NASA SUPPLEMENTAL AUTHORIZATION FOR FISCAL YEAR 1959

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HEARINGS

BEFORE THE

NASA AUTHORIZATION SUBCOMMITTEE

OF THE

COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES

UNITED STATES SENATE

EIGHTY-SIXTH CONGRESS

FIRST SESSION

ON

S. 1096

A BILL TO AUTHORIZE APPROPRIATIONS TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION FOR SALARIES AND EXPENSES, RESEARCH AND DEVELOPMENT, CONSTRUCTION AND EQUIPMENT, AND FOR OTHER PURPOSES

FEBRUARY 19 AND 20, 1959

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NASA SUPPLEMENTAL AUTHORIZATION FOR FISCAL YEAR 1959

THURSDAY, FEBRUARY 19, 1959

U.S. SENATE,
SUBCOMMITTEE OF THE COMMITTEE ON
AERONAUTICAL AND SPACE SCIENCES,
Washington, D.C.

The subcommittee met, pursuant to call, at 2:40 p.m., in room 212, Old Senate Office Building, Senator John Stennis presiding.

Present: Senators Stennis, Young of Ohio, Cannon, Wiley, Smith, and Martin.

Also present: Kenneth E. BeLieu, staff director; Max Lehrer, assistant staff director; Everard H. Smith, Jr., counsel; Dr. Glen P. Wilson, chief clerk; Dr. Earl W. Lindveit, assistant chief clerk; and Mrs. Eilene Galloway, special consultant.

Senator STENNIS. The Senate committee will please come to order.

We are glad to have our photographer friends with us. I hope that they have either completed their picture taking or have arranged to complete it soon after the testimony starts, because the continuous activity does detract from the testimony.

If it is agreeable now to the subcommittee, the Chair proposes to let the witnesses proceed. We are very glad to have you gentlemen with us and you may proceed with your statements as you see fit, either by reading them or by placing them in the record and explaining such high points as you wish.

We do hope that there will not be any interruption unless it be an emergency of some kind. After the witnesses have finished their statements, the Chair will propose that each member of the subcommittee will have 5 minutes for questions before we proceed to another member. In that way, each one will have a chance to ask some questions.

This presentation is estimated to take more than just this afternoon. Our friends are prepared to come back tomorrow, and if it fits everyone's schedule for this afternoon we can stay here about 2 hours and then recess until tomorrow morning at 10:30, at which time we will be certain to finish during the morning hours.

The Chair at this time would like to make a brief introductory statement.

The National Aeronautics and Space Administration, established last year, has broad jurisdiction over vitally important aeronautical and space activities of the Government. It needs appropriation authorization to move forward on its programs for the remainder of fiscal year 1959 and for the fiscal year 1960.

Even with good management on the part of NASA, I predict this program will, in a few years, be costing the American taxpayers

several billion dollars a year. The people should be advised of the prospective costs now, and, Dr. Glennan, I have read a portion of your statement this morning in which you come right out and put up those warning signs. I think that is the way to present the picture. Not a single essential dollar should be denied or spared. At the same time, none should be wasted. Duplications in programs and facilities should be avoided. NASA is a new agency making a new start, and it should avoid the errors of costly duplication found elsewhere.

We have no choice as to supporting a major space program since we are already living in the space age. No one can say where we would be today as a nation had we not devoted major effort to aviation progress following the first successful flight 56 years ago; nor, if we, as a nation, had failed to move forward with radio and television and other communication programs, or failed to exploit advances in electronics or atomic power.

It would be just as grave a mistake to fail to move forward with the utmost speed into a modern space program. We have a double interest in this vital area. One is the obvious military importance of space, and the other is the peaceful benefits that may be derived for all mankind through better weather forecasting, improved communications, et cetera.

Let us proceed with a sound space program that will excel.

To assure authorization for present needs, the Committee on Aeronautical and Space Sciences has separated its consideration of NASA needs for 1959 from the agency's requirements for 1960.

Chairman Johnson's request for early consideration of pending legislation is to be inserted in the record here.

(The document referred to is as follows:)

U.S. SENATE,
COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES,
February 18, 1959.

Hon. JOHN STENNIS,
U.S. Senate, Washington, D.C.

DEAR JOHN: I am writing to request that you serve as chairman of a subcommittee for the purpose of studying authorization legislation for the National Aeronautics and Space Administration.

Senators Young, Dodd, Cannon, Smith, and Martin have been asked to serve as members of this subcommittee.

Mr. Max Lehrer has been designated to serve as the staff member to assist the subcommittee.

Senator Bridges and I have introduced S. 1096, a bill to authorize appropriations to the National Aeronautics and Space Administration for the fiscal year 1959.

As S. 1096 is a bill coming within the area of responsibility of your subcommittee, I would appreciate its early consideration by the subcommittee.

With warm regards.

Sincerely,

LYNDON B. JOHNSON, *Chairman.*

Senator STENNIS. Witnesses at the next 2 days' hearings will discuss and be questioned on the overall summary of NASA space programs. Many key aspects of the overall national effort will be explored. Others will be deferred, but those covered will be studied in sufficient detail for the committee to act promptly and effectively in providing additional authority for funds for fiscal year 1959, with assurance that the adjustments in the 1959 program lead smoothly into contemplated operations for 1960 and future years.

Our first witness this afternoon is Dr. T. Keith Glennan, Administrator of the National Aeronautics and Space Administration.

Dr. Glennan, we are certainly glad to have you and the other witnesses with us, and may I at this time say one word to the membership of this subcommittee: The occupant of the chair is delighted to serve here with you on this important measure and hear testimony of these most important witnesses on this bill.

Now we are here as members of this subcommittee on an equal footing. It is not my subcommittee. It is our subcommittee, and you carry the full responsibility with your position on it, which is equal to mine or to anyone else's. I appreciate the attention you are giving to this work.

The main emphasis of this particular series of hearings will be directed toward justification for authorization of appropriations in the amount of $48,354,000 as embodied in Senate bill 1096. This bill incorporates the amounts included in the President's budget.

S. 1096 will be inserted in the record at this point.

(S. 1096 is as follows:)

[S. 1096, 86th Cong., 1st sess.]

A BILL To authorize appropriations to the National Aeronautics and Space Administration for salaries and expenses, research and development, construction and equipment, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That (a) there is hereby authorized to be appropriated to the National Aeronautics and Space Administration for the fiscal year 1959 the sum of $48,354,000 as follows:

(1) For an additional amount for "Salaries and expenses", $3,354,000.

(2) For an additional amount for "Research and development", $20,750,000.

(3) For an additional amount for "Construction and equipment", $24,250,000 as follows:

(A) Jet Propulsion Laboratory, Pasadena, California: New facilities, improvements to existing facilities, and approximately seventy acres of land, $9,000,000; and

(B) Various locations: Global range tracking and communication facilities and equipment, and propulsion development facilities, $15,250,000.

(b) Authorization is hereby granted whereby either the amount prescribed in subparagraph (A) or the amount prescribed in subparagraph (B) of subsection (a)(3) may, in the discretion of the Administrator of the National Aeronautics and Space Administration, be varied upward 5 per centum to meet unusual cost variations, but the total cost of all work authorized under such subparagraphs shall not exceed a total of $24,250,000.

SEC. 2. Any amount, not to exceed $500,000, of the funds appropriated pursuant to authorization of subsection (a)(3) of the first section for the construction of facilities described under such subsection may, with the approval of the Bureau of the Budget, be used for the construction of new research facilities or for the modification of existing research facilities not specifically authorized in this Act, if such construction or modification is deemed by the Administrator of the National Aeronautics and Space Administration to be of greater urgency than the construction of any facility authorized by this Act; but no such funds shall be used for the construction or modification of any facility if funds for such construction or modification have been previously denied by the Congress.

Senator STENNIS. Now if all the witnesses will just stand, you will all be sworn at the same time.

Do you, and each of you, solemnly swear that the testimony you are about to give in this matter will be the truth, the whole truth, and nothing but the truth, so help you God?

Dr. GLENNAN. I do.

Dr. DRYDEN. I do.

Dr. SILVERSTEIN. I do.

Senator STENNIS. Dr. Glennan, we are especially glad to have you here and you can proceed in your own way. You do have a prepared statement and each member of the committee has one before us.

Proceed, Doctor.

(The biographical sketches of Dr. Glennan, Dr. Dryden, and Dr. Silverstein follow:)

T. KEITH GLENNAN, ADMINISTRATOR

T. (Thomas) Keith Glennan took the oath of office as Administrator of the National Aeronautics and Space Administration on August 18, 1958, after his appointment by President Dwight D. Eisenhower. He became the first Administrator of the new Government organization after its creation under the National Aeronautics and Space Act of 1958.

As Administrator, Dr. Glennan heads a staff of scientists, engineers, and technicians, and other employees engaged in research and development in aeronautics and space matters. The NASA is an independent agency reporting directly to the President. In his capacity as the principal administrative officer of the NASA, Glennan is a member of the National Aeronautics and Space Council.

Glennan is president on leave of the Case Institute of Technology, Cleveland, Ohio, which he has headed since 1947.

He was born in Enderlin, N. Dak., on September 8, 1905. Dr. Glennan spent most of his youth in Eau Claire, Wis., where he attended high school, worked at a variety of odd summer jobs, and spent 2 years at State Teachers College. In 1927, after working his way through college, Glennan was graduated with honors from the Sheffield Scientific School of Yale University with a degree in electrical engineering.

Following graduation, Glennan became associated with the newly developed sound motion-picture industry, and spent 2 years in Europe supervising the installation of sound systems, for the Western Electric Co. He later became assistant general service superintendent for Electrical Research Products Co., a subsidiary of Western Electric. In 1935, he joined Paramount Pictures, Inc., in Hollywood, becoming studio manager in 1939. In 1941 Glennan was associated briefly with Vega Airplane Corp., returning to the motion-picture industry as studio manager of Samuel Goldwyn Studios.

The NASA Administrator joined the Columbia University Division of War Research in 1942, serving through the war, first as Administrator and then as Director of the U.S. Navy's Underwater Sound Laboratories at New London, Conn. For his contributions to research during World War II, he was awarded the Medal for Merit.

At the end of the war, Glennan became an executive of Ansco, Binghamton, N.Y. From this position he was called to the presidency of Case. From October 1950, to November 1952, concurrent with his Case presidency Glennan served as a member of the Atomic Energy Commission.

While Glennan was president of Case, important progress was made in increasing both the quality and quantity of the faculty, student body, and physical plant. A major building program was initiated through which the floorspace of the campus was more than doubled. Important curricular changes emphasizing the role of the humanities in engineering education were initiated. During his 11-year administration, Case was transformed from a primarily local institution into one that ranks with the top engineering schools in the Nation.

Glennan has been extremely active in national and local affairs. He was chairman of the board of the Institute for Defense Analysis, on the board of the National Science Foundation, and on the Council on Financial Aid to Education. He was a member of the General Advisory Committee of the Atomic Energy Commission. As chairman of the Metropolitan Services Commission of Cleveland, Glennan was concerned with improving government services in the Greater Cleveland area, and in the development of a $175 million cultural and educational center in that city. He was a trustee of the Cleveland Clinic Foundation. He was a member of the boards of the Cleveland Electric Illuminating Co., the Clevite Corp., Standard Oil (Ohio), and the Harris-Intertype Corp.

Glennan continues as a trustee of Case but has taken a leave of absence from the presidency of the institute to become NASA Administrator. When he assumed his duties with NASA, he resigned from all of his other educational and business obligations.

Glennan is a fellow of the American Academy of Arts and Sciences, and member of Sigma XI, Tau Beta Phi, and Chi Phi. He has been awarded honorary degrees of doctor of science from Oberlin College, Clarkson College of Technology, and John Carroll University, and a doctor of engineering degree from Stevens Institute of Technology and Fenn College.

He is married to the former Ruth Haslup Adams, daughter of the late Dr. Thomas Sewell Adams, eminent Yale professor and tax authority, whom Glennan served as a chauffeur while attending college. He has four children: the eldest, Thomas Keith, Jr., is attending graduate school at the Massachusetts Institute of Technology; Catherine, a recent graduate of Swarthmore and now a graduate student in library science at Western Reserve University; Pauline, who is about to graduate from high school, and Sarah, from junior high school.

Hugh L. Dryden, Deputy Administrator

Hugh Latimer Dryden assumed the duties of Deputy Administrator of the National Aeronautics and Space Administration on August 19, 1958, upon appointment by President Eisenhower. He became the first Deputy Administrator of the NASA after its creation by Congress in the National Aeronautics and Space Act of 1958.

Dr. Dryden's duties in large part are concerned with the direction of the NASA staff of civilian scientists, engineers, and technicians engaged in aeronautical and space research and development. He serves as the Administrator's alternate on the National Aeronautics and Space Council.

At the time of his appointment, Dr. Dryden was Director of the National Advisory Committee for Aeronautics, the research agency which became the nucleus of the NASA. He headed the staff of the NACA from 1947 to 1958.

Born July 2, 1898, in Pocomoke City, Md., Dryden was reared in Baltimore, where he attended local public schools. He worked his way through Johns Hopkins University in 3 years, earning his bachelor of arts degree in 1916. Joining the staff of the National Bureau of Standards in 1918, his interest centered on the study of fluid dynamics. Meanwhile, he continued his courses at Johns Hopkins, which granted him a Ph. D. in 1919.

Dr. Dryden was promoted in 1920 to head the Bureau's aerodynamics section; and in 1934 he was appointed to Chief of the Mechanics and Sound Division. He became Assistant Director of the Bureau in January 1946, and Associate Director 6 months later.

Although Dryden performed important research at the Bureau on building materials and structures, his main field of interest was in aerodynamics, particularly turbulence and control of the boundary layer. He made some of the earliest studies in this country of airfoil characteristics near the speed of sound.

Dryden resigned from the Bureau of Standards, after 29 years of service to head the NACA, as Director of Aeronautical Research of the NACA, on September 1, 1947. Two years later his title was changed to Director.

In 1938, Dryden was the first American selected to give the Wright Brothers lecture before the Institute of Aeronautical Sciences. He has served with a number of technical groups advising the armed services on aeronautical matters and guided missiles during and since World War II. He was awarded the Presidential Certificate of Merit for his leadership in the development of the Bat, the first American guided missile successfully used in combat. He was given the Medal of Freedom for his work in 1945 as Deputy Scientific Director of a group appointed to advise the Army Air Force on future research and development.

In 1948 he was appointed an Honorary Officer, Civil Division, Order of the British Empire, and the following year was selected to deliver the Wilbur Wright memorial lecture to the Royal Aeronautical Society in London. Other awards include the 1950 Daniel Guggenheim Medal, the 1955 Wright Brothers Memorial Trophy, the Baltimore City College Hall of Fame (1958), and the 1958 Career Service Award of the National Civil Service League.

During his scientific career, Dryden has been a frequent contributor to professional and technical journals. His professional affiliations include the National Academy of Sciences, of which he is home secretary; International Union of Theoretical and Applied Mechanics, Institute of Aeronautical Sciences, Royal Aeronautical Society, American Academy of Arts and Sciences, American Physical Society, American Rocket Society, American Association for the Advancement of Science, American Society of Mechanical Engineers, Sigma Xi, Sigma Tau, and Phi Beta Kappa. He holds honorary degrees from the Polytechnic Institute of Brooklyn, New York University, Rensselaer Polytechnic Institute, University of Pennsylvania, Western Maryland College, Johns Hopkins University, and the University of Maryland.

He is currently a member of several scientific committees advising Government agencies, including the Department of Defense, U.S. Army, U.S. Air Force, Science Advisory Committee to the President, Interdepartmental Committee on

Scientific Research and Development, and the NATO Advisory Group for Aeronautical Research and Development.

Dryden is married and has three children, a son, Hugh Latimer, Jr., and two daughters, Nancy Travers Dryden and Mrs. Andrew Van Tuyl, of Silver Spring, Md. The Dryden family lives at 5606 Overlea Road, Washington, D.C.

Abe Silverstein, Director of Space Flight Development

Abe Silverstein is Director of Space Flight Development at the National Aeronautics and Space Administration headquarters in Washington, D.C. Before the NASA was established, on October 1, 1958, he was Associate Director of the Lewis Flight Propulsion Laboratory, Cleveland, Ohio, a research center of the National Advisory Committee for Aeronautics, which formed the nucleus of the NASA.

Silverstein directs those NASA programs aimed at the development of space flight. Development programs under his direction include space probes and manned and unmanned satellite systems. He is also responsible for the development of propulsion systems capable of powering these space vehicles.

Silverstein is a native of Terre Haute, Ind., where he attended local grammar and high schools. He earned a bachelor of science in mechanical engineering degree in 1929, and a mechanical engineering degree in 1929, and a mechanical engineer professional degree in 1934, from Rose Polytechnic Institute. He was awarded an honorary Ph. D. by Case Institute of Technology in 1958.

Silverstein joined the National Advisory Committee for Aeronautics in 1929, and soon after helped design the full-scale wind tunnel at the Langley Aeronautical Laboratory. He later was placed in charge of this facility, and directed research which increased the high-speed performance of most of the combat aircraft of World War II. This work was recognized as a major factor in gaining U.S. air superiority during the war.

In 1943, he was transferred to the Lewis Laboratory at Cleveland to select and train a staff which he directed in research at the altitude wind tunnel. These investigations led to significant improvements in both reciprocating and early turbojet aircraft engines. He also pioneered with large-scale ramjet engines, now used on certain missiles.

At the end of World War II, Silverstein was directing the work at several major research facilities at Lewis. He directed the erection of the $9 million NACA 8 x 6-foot supersonic wind tunnel, first operated in 1949, and the $33 million NACA 10 x 10-foot supersonic wind tunnel, completed in 1956. These facilities, the largest wind tunnels of their kind in the world, have greatly accelerated the development of supersonic aircraft. In 1952, he was appointed associate director of the Lewis Laboratory, a post he held until he was named to the headquarters staff of the NASA.

Silverstein was a member of several NACA committees and subcommittees including: Committee on Aerodynamics, 1946–47; Subcommittee on Self-Propelled Guided Missiles, 1945–47; Subcommittee on Internal Flow, 1947; Subcommittee on High-Speed Aerodynamics, 1945–57; Committee on Power Plants for Aircraft, 1951–57; and the Special Committee on Space Technology, 1958.

He served as chairman of the Cleveland section of the Institute of Aeronautical Sciences, 1946–47. He was a member of the Committee on Arrangements for the joint meeting of the Institute of the Aeronautical Sciences and the Royal Aeronautical Society, held in New York City in 1949. The Assistant Secretary of Defense for Research and Development appointed him a member of the Technical Advisory Panel on Aeronautics for the year 1955, and as chairman of the Ad Hoc Working Group on Rockets for 1956. He was a member of the Scientific Advisory Board of the Chief of Staff, U.S. Air Force, for 1956 and 1957, and Chairman of the OASD Technical Advisory Panel on Aeronautics, Ad Hoc Group on Propulsion for Aircraft and Missiles. He was a member of the Assistant Secretary of Defense's steering group of the Advisory Panel on Aeronautics for 1958.

Silverstein was American representative to the joint meeting of the Institute of the Aeronautical Sciences and the Royal Aeronautical Society in London in 1947. He delivered the annual Wright Brothers lecture before the IAS in 1949.

He is a member of Tau Beta Pi, and a Fellow of the Institute of the Aeronautical Sciences.

Silverstein, his wife Marion, and their three children, Joseph, Judith, and David, live at 7205 Rollingwood Drive, Chevy Chase, Md.

TESTIMONY OF DR. T. KEITH GLENNAN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY DR. HUGH L. DRYDEN, DEPUTY ADMINISTRATOR, NASA

Dr. GLENNAN. Mr. Chairman, we are glad to have an opportunity to appear before you and the members of the subcommittee and tell you a little bit about our business and the manner in which we propose to go about it from this point on, particularly with respect to the management of funds.

I would like to read the prepared statement because I think it does give me an opportunity to point out rather clearly and exactly what we are about.

Events of the month since I was last privileged to appear before your committee have served to bring into sharper focus certain aspects of our national space program. NASA is nearly 5 months old. We have been picking up speed in the development of our program to the extent that it is now possible to delineate in greater detail some of the uses we can make of satellites and probes sent into space.

BOOSTER ROCKET DEVELOPMENT

As a really basic ingredient in our business, as I outlined to the committee at the time of our earlier meeting, we have undertaken—working with the Department of Defense—an integrated program of booster rocket development to provide the means to put into orbit or send on long journeys into space the larger-sized payloads our scientists need. That program is already being prosecuted with great vigor and before the end of 1960, the first of the building-block units of this national booster program will have become available. Not until then will the scientists be able to start such second-generation experiments as those employing advanced meteorological and communications devices and the astronomical telescope in space. If we knew of a better way to make such improved booster capabilities available earlier, we would do it.

SPACE TECHNOLOGY IMPROVEMENT

Concurrently with the development of adequate boosters, there must be carried on very substantial improvement of our space technology capabilities. We must, for example, learn how to provide a stable space platform for the astronomical telescope. We must provide power sources that will operate, for longtime periods, both the data-gathering instrumentation we send into space, and also the telemetry equipment that sends the data back to earth.

Packaging of the instrumentation, power supplies, telemetry equipment, and the like, into a payload system which can be mated to the vehicle available for the experiment requires that our national capacity for this kind of service be enlarged. Presently, groups with direct experience in payload packaging include the Jet Propulsion Laboratory and the VANGUARD group within NASA, also the Space Technology Laboratories and the Army Ballistic Missile Agency. There are, in addition, a number of industrial organizations with the

necessary basic capabilities and it is planned to encourage participation in this work by these latter groups.

TRACKING AND TELEMETRY

Data handling for the satellite and probe operations now planned is still another aspect of the total problem. We must be prepared to bring back to a central point all the records collected by the worldwide net of stations, and there to make useful copies of the magnetic tapes or oscillograph records for distribution to the individual experimenters for analysis.

Already, the number of satellites and probes required for the presently planned space sciences program is far larger than was anticipated, even a few months ago, by those concerned with tracking and telemetry reception. Keeping track of the satellites and probes that soon will be traveling across the oceans will tax our operational facilities to the utmost.

The intensive efforts we are now making to build up our tracking and telemetry-reception capabilities are designed to enable us to keep pace with these expanding requirements.

NATIONAL SPACE PROGRAM

In planning the national space sciences program, a major difficulty has been to devise experiments within the critical weight and size limitations imposed by our present ability to send only very small payloads into space. The work the scientists will be doing with these presently scheduled 30 satellites and probes might be called first generation experiments.

In the development of this program, NASA has been materially assisted by advice from the Space Science Board of the National Academy of Sciences and also from other specialists and experts in the scientific community. In the conduct of our satellite and space probe experiments, we shall have broad participation by the scientific community and industry, as well as by other agencies of the Government, especially in the preparation of the instrumentation payloads.

We expect also to achieve a beginning measure of participation by the international scientific community, working with the Committee on Space Research, known as COSPAR, of the International Council of Scientific Unions.

The space sciences program as presently structured will be subject to continuing review, amplification, and modification. For convenience, the program has been divided into several areas of interest, including atmospheres, ionospheres, energetic particles, electric and magnetic fields, gravitational fields, astronomy, and biosciences.

There will be, of course, considerable overlap among the different areas, and study of these various interrelationships will be an important part of the program.

The vehicles to be used in performing the programed space sciences experiments will be used for about 15 satellites and probes in calendar 1959 and as many more in calendar 1960. It is intended also to use some 40 sounding rockets in calendar 1959 and about a hundred in 1960. These are planning figures—they may change to some extent—but they are of the right order of magnitude.

Later presentations by NASA staff will provide more detail about these programs and, of course, about other activities planned for fiscal 1960 and the remainder of the current fiscal year.

PERSONNEL AND FACILITIES INHERITED BY NASA

Now, I'd like to discuss briefly certain aspects of our personnel and facilities planning which are fundamental to our operations.

As I have stated before, one of the very great assets of NASA in these formative months has been the staff of nearly 8,000 scientists, engineers, and supporting personnel, the $350 million value of the finest of research facilities, and the comprehensive flight research programs that we inherited from the National Advisory Committee for Aeronautics.

The record plainly shows that there isn't an airplane flying today that doesn't reflect in many important ways the good results of NACA research. The same can be said for our missiles.

For the past several years—before establishment of NASA—the research programs at the NACA installations were being oriented increasingly to problems of space flight. This reorientation is being extended, and we intend to do everything possible to assure that these research centers continue to perform work of great value. On the other hand, we must be vigilant in assuring that these same great centers program an adequate amount of research and development to support the rapidly changing aeronautics industry—both civilian and military.

One vitally important action will be to provide the modern research facilities required, and we have budgeted $20,800,000 in fiscal 1960 for this purpose.

Looking to the future, it may be expected that the annual expense of maintaining the necessary top quality of the research equipment will be as high, or even higher.

At the present time, we plan no enlargement of staff at the former NACA research centers. The expansion of NASA effort, including deep involvement in such research, development, and operational areas as electronics, guidance, rocket systems, et cetera, is being accomplished elsewhere both by the acquisition of a going concern, the Jet Propulsion Laboratory, operated by the California Institute of Technology, and by the development of additional in-house capability of the new NASA Space Projects Center, which you recall is at Beltsville.

With the acquisition of the Jet Propulsion Laboratory, NASA obtained a high order of competence in electronics, guidance, propulsion, systems analysis, and in tracking and telemetry.

Work is still in progress there on the Army's Sergeant missile, but by July 1 of next year, the project will have been phased out, and the entire 2,300-man JPL organization will be working full time on NASA space programs.

ARMY BALLISTIC MISSILE AGENCY

NASA does require, however, the additional capability to accomplish the necessary assembly and ground test of space vehicle systems, and also to supervise the subsequent launching operations. We had

hoped, as I have previously said, to obtain this capability last October, together with the services of a highly competent engineering and design group that could become an integral part of our organization in the planning and executing both short- and long-term programs in the development of boosters and vehicular systems, when we sought the transfer to NASA of a portion of the Army Ballistic Missile Agency at Huntsville, Ala.

As I told your committee last month, the Department of Defense felt unable to agree to that transfer. Instead, arrangements were made for the Army to be "completely responsive" to our requests for the performance of such work as we might desire, and which the Army feels can be done without interference to its military subjects. This arrangement will be reexamined during the current year; meantime, the Army has given every assurance of an earnest desire to cooperate, and we intend to make the fullest use possible, under the circumstances, of the ABMA capabilities.

VANGUARD DIVISION

NASA also acquired from the Navy, on October 1, the Vanguard group, headed by Dr. John P. Hagen, together with 25 persons from other divisions of the Naval Research Laboratory who had spent substantially full time in support of this project, a total of 158 individuals.

The Vanguard project people transferred to NASA so that they could continue to work on this and future space science programs.

This group, beginning in 1955, had produced in a very short time a satellite-launching vehicle that incorporated much in the way of advanced design. Its early flight experience was substantially the same as that of other missiles, whose failures and successes were not made public.

Prior to Tuesday of this week, I had told Adm. Rawson Bennett, Chief of Naval Research, and Capt. P. H. Horn, commandant of the Naval Research Laboratory, that we in NASA were fully convinced of the inherent validity of the Vanguard project. And, when we took over on October 1, NASA did its utmost to help the Vanguard project group in their work.

What happened at 10:55 the morning of the 16th of this month at Cape Canaveral justified our confidence and our effort.

Perhaps even more important, Vanguard's injecting into orbit of the cloud-cover experiment prepared by the U.S. Army Signal Research and Development Laboratory at Fort Monmouth, N.J.—and the model of it is right over here—marked the beginning of what may well become a new day in weather forecasting. It was just a first step, but it was a step of very great significance.

I am sure that Dr. John Hagen and his very competent people will continue to be employed to good purpose with even broader scope than in the past.

NASA PERSONNEL COMPLEMENT

To recapitulate, NASA prefers to keep its own organization as small as is possible, consistent with performance of missions.

Using the NACA personnel complement at the beginning of fiscal 1959 of 7,892 as a frame of reference, we expect to count 8,961 em-

ployees on July 1, this year, and 9,988 one year later, an increase of about 1,000 a year.

If, however, our experience demonstrates the necessity for us to develop from scratch the in-house capabilities we have hoped to acquire from ABMA, then we will need to enlarge our personnel complement by as much as 2,500 employees, and, of course, will have to provide the new facilities needed for their use.

The fiscal 1959 supplemental estimate of $48,354,000 includes $3,354,000 for salaries and expenses. This item is to cover the cost of the salary increases provided for by the Classified Pay Act of 1958, and does not provide for additional positions.

PROJECT MERCURY

The $20,750,000 in the supplemental estimate for research and development is entirely ear-marked for our manned space flight program—Project Mercury. It is apparent that full exploitation of the potentialities of space flight for the benefit of mankind will be contingent upon the development of practical capabilities for operating manned space vehicles.

The additional funds we are requesting for Project Mercury are to permit us to progress as rapidly as possible in this effort to prove our ability to send man into orbital flight and return him safely to earth.

The remainder of the 1959 supplemental request consists of $24,250,000 of which the sum of $9 million is required for new facilities, improvements to existing facilities, and about 70 acres of land, for the jet propulsion laboratory in Pasadena, Calif.; $12,050,000 for new tracking facilities which will be a part of the national space tracking system, and $3,200,000 for propulsion-development facilities to be used in testing of the 1 to 1½ million pound thrust, single chamber rocket engine.

FACILITIES RELOCATION

The jet propulsion laboratory money, in large part, is to permit relocation of various rocket test facilities and related equipment to a nonhazardous location where safety code standards can be met.

At the present time, all but 10 of the 92 facilities on the laboratory site in Pasadena are nonconforming, and consequently to make necessary modifications to existing facilities to meet changing requirements would involve us in major alterations to bring the installation up to "code."

The necessary land acquisition will cost $375,000; relocation of utilities will total $2,775,200, and of test facilities, $1,931,800.

Modernization of support facilities will cost $2,255,000, and necessary new facilities will cost $1,488,000 plus $175,000 for a new substation and transformer pad.

I might say, Mr. Chairman, at this point, this particular amount of money—this series of tasks that I just outlined had been programed in JPL's discussions with the Army before we took over the laboratory last December.

TRACKING FACILITIES

The $12,050,000 requested for tracking facilities is needed now, because of the long lead times of much of the electronic gear.

Extension of the Minitrack electronic tracking system by establishment of four new stations, located in Alaska, continental United States, Newfoundland, and Europe, together with installations of improved equipment at other stations, will cost $3,300,000.

Installations of radar dishes in Australia and South Africa will, when tied to the NASA–JPL station at Goldstone, Calif., enable the tracking of probes sent deep into space.

The $3,500,000 will permit initiation of the procurement of the longlead time basic precision radar systems.

The remaining $5,250,000 is for precision radar acquisition, tracking, communications, and associated systems, at locations in southern Texas and other areas, for use in tracking the midcourse reentry and landing of Project Mercury orbital capsules—man-in-space capsules—as they start back in the atmosphere to be picked up on the east coast.

FISCAL YEAR 1960 REQUEST

To make this picture complete, I would like to speak very briefly about our budget request for fiscal year 1960 and to make a few remarks about the future costs of these operations.

The NASA budget estimates for fiscal 1960 total $485,300,000. They include increases in salaries and expenses and construction and equipment items of $11,330,000 and $9,800,000, respectively, as compared to the same categories in the fiscal 1959 appropriations.

The research and development request for $333,070,000 is an increase of $129,460,468 over fiscal 1959. These requests will, of course, be discussed in detail by others of the NASA staff at an appropriate time.

The point I want to make at this time is that these increases represent the accelerated level of space effort which we believe we can justify at this time.

I emphasize at this time because we are now in the formative stages of one of the most challenging programs ever undertaken by the United States.

The budget we have requested is what we need to do our job at present. We shall, of course, carry on a continuing, intensive review, not only of our presently scheduled programs, but also of what we should or could be doing in addition.

FUTURE BUDGET REQUESTS

I should probably add the comment that, in my opinion, this is the last time that, at least in the foreseeable future, NASA will be requesting a budget of one-half billion dollars.

If anything, the level of our space effort today is minimal if we are to reach our goals as promptly as we must. In these early stages of organizing, and planning, and beginning our programs, however, there are definite limits to the sums of money we can usefully spend.

Today, we are making the downpayments on programs that, inevitably, will cost very much more in the years ahead. Project Mercury is budgeted at $37,661,200 in fiscal 1959; we are asking for $20,750,000 in supplemental funds before you now.

The 1960 cost of Project Mercury is $70 million, and before we have completed this first U.S. effort to put man into space, the bill will have exceeded $200 million.

The one 1½ million pound thrust engine is a $12 million item in the 1959 budget; its cost increases to $30,200,000 in the 1960 budget.

Before this single-chamber booster has been brought to a state of usefulness, the cost will have exceeded approximately $200 million.

Every time one of these giant boosters is used to send many tons of payload into space, we will be spending more than $20 million.

I don't want to belabor the point, but I need to cite one final figure. The cost of the national booster program, to provide the building block units of basic rocket motors needed for our space programs, will exceed $2 billion in my opinion.

These are facts that must be considered now. The cost of our space programs will continue, year after year, and it will increase, year by year.

RESULTS OF SPACE EXPERIMENTS

I couldn t begin to say precisely what the payoffs will be, or how soon they will be realized. We expect that in the relatively near future, satellites will be widely used in meteorology—witness this Vanguard II cloud cover experiment—and in worldwide communications.

Experts in those fields have estimated that the value of such advances will be counted in the billions of dollars.

Very great as such returns will be from our work in space, I have an inner conviction that in the years to come, there will be other gains from what we learn in space. They will be ones we don t even dream of today. They will be ones that will dwarf those we can only dimly see today.

Mr. Chairman, that completes my prepared statement. I will be very happy to answer questions, as you will.

Senator STENNIS. Thank you, Dr. Glennan. That is a very fine statement. It is clear and concise and to the point, and covers the overall subject. There is a frankness about those figures that I have already commended you for, and I think that Congress ought to have the picture as you can see it now, especially on the money issue.

I notice you have those models over there. Did you have in mind, Doctor, exhibiting those to the committee here on the table, or was someone else to do that?

Dr. DRYDEN. Cortright is going to do this later, or now if you like.

Senator STENNIS. I think this will help us understand some of the items mentioned, if we could have it presented now, and without interruptions, then we could get back to Dr. Glennan.

Is that Mr. Cortright? You are on the list as Chief of the advanced technology program, Office of Space Flight Development. Is that correct?

Mr. CORTRIGHT. Yes, sir.

Senator STENNIS. And you are going to give us a demonstration now of the application of the satellites?

Mr. CORTRIGHT. Later on when I get into a little more detailed discussion on meteorology and the use of a meteorological satellite, I will have more to say about this.

Senator STENNIS. Just point out the major areas of interest.

STATEMENT OF EDGAR M. CORTRIGHT, CHIEF, ADVANCED TECHNOLOGY PROGRAM, NASA

Mr. CORTRIGHT. This is a model of the Vanguard rocket, a three-stage vehicle which was used to put the satellite into orbit.

DESCRIPTION OF VANGUARD ROCKET AND ITS DEVELOPMENT

The Vanguard rocket was developed by numerous contractors under the overall direction of the Vanguard Division under Dr. Hagen, as you have heard. The payload itself was developed by the U.S. Army Research and Development Laboratory of the Signal Corps at Fort Monmouth. It is a 20-inch diameter sphere weighing 21½ pounds, containing two photoelectric cells which observe the surface of the earth.

The photocells are shown here and they view out in diametrically opposite directions at an angle of 45° to the spin axis, which is here.

By choosing a geometry such as this, there is always one photocell which will scan the ground, for a photocell isn't like a television camera which takes an entire picture at one time. It looks at a single point, and the scan is generated by both the travel of the satellite over the earth's surface, and its spin, so you continually scan different lines of the earth's surface with it.

This again will become more clear later when I testify.

Now, there are other pieces of equipment within the satellite. There is a recorder, a magnetic tape recorder, a command receiver, a data transmitter, a beacon transmitter, and a mercury battery which goes to complete the payload.

Unless there are more questions, I will defer until a further time.

Senator STENNIS. That gives us a general idea about it and I thought that would be helpful. That won't interfere with your presentation later.

Dr. GLENNAN. Mr. Chairman, I don't believe in sailing under false colors and I think it only proper to point out that this vehicle and the satellite was largely developed by the Vanguard Division of the Naval Research Laboratory when it was really a part of the Navy, and we are delighted to have this group with us today. But I do want the people to know that the Navy had a great deal to do with supporting this.

Senator STENNIS. That is very commendable, and your statement covers that, but you especially point it out now.

Thank you, Mr. Cortright.

On this point, Doctor, you took over the Vanguard and then you inherited this fine group of scientists and assistants that came over from NACA?

Dr. GLENNAN. That is right, sir.

Senator STENNIS. Which has been engaged now for several years in various projects.

Dr. GLENNAN. That is correct.

Senator STENNIS. That is for the information of those that might not remember about it.

SITUATION AT ARMY BALLISTIC MISSILE AGENCY

I will be very brief in my original questions here. I was attracted by what you said about the situation down at the arsenal at Huntsville and the temporary arrangement, and quoting from your statement, you said:

> If, however, our experience demonstrates the necessity for us to develop from scratch the in-house capabilities we have hoped to acquire from the Army Ballistic Missile Agency, then we will need to enlarge our personnel complement by as much as 2,500 employees, and, of course, will have to provide the new facilities needed for their use.

Now that means, as I understand it, unless you do acquire that Agency you will have to start building for these 2,500 additional employees. Is that correct?

Dr. GLENNAN. Mr. Chairman, unless we find that it is possible under the present arrangements with ABMA to do the job that we think has to be done to discharge our responsibilities, then we will have to seek an alternate way of doing it, and the alternates available to us are acquiring ABMA or building our own capability by employing people and building a laboratory into which those people can be placed.

Senator STENNIS. Yes.

Dr. GLENNAN. When we looked at this problem just after I had come aboard, we were looking at the probable investment of some $60 million in building a laboratory to house these people and the employment of some 2,500 people in competition with existing installations and so we did take a look at a great many activities in the country in an attempt to find out if we can avoid this kind of an expenditure.

That is what led to our asking for the Jet Propulsion Laboratory and ABMA. Jet Propulsion Laboratory was transferred to us and we are delighted that they are part of our organization. ABMA was not, and we are using them as a contractor.

The problem is that one doesn't quite use a contracting agency in the same way one does one's own organization. It is not an integral part of the organization, participating in every portion of our planning, monitoring the activities of the other organizations that might be under contract to us.

Senator STENNIS. Now, when do you expect a decision on this matter?

Dr. GLENNAN. I should say now it will be within the next 10 or 11 months. In the meantime, we are, as I say, exploring the extent to which the contractual method solves our problems and we are also utilizing some of our own laboratory personnel at other laboratories and some of the Jet Propulsion Laboratory personnel to carry on the work.

Senator STENNIS. If you should make a decision within the next few months and require these extra employees and extra buildings, will you have to ask for additional funds in the 1960 budget?

Dr. GLENNAN. That is right, sir, we will have to come back to you.

Senator STENNIS. With a supplemental request, if the decision is made in time for the Congress to act on the situation.

Dr. GLENNAN. That is right.

Senator STENNIS. Do you see a possibility or a probability of your being crippled for the lack of funds in the meantime?

Dr. GLENNAN. I think not, sir.

AVAILABILITY OF TECHNICAL AND SCIENTIFIC PERSONNEL

Senator STENNIS. Well, what has been your situation now, coming into this picture just 5 months ago, with reference to the availability of technical and scientific personnel that you have needed?

Dr. GLENNAN. I think we have been able to employ the additional scientific and technical personnel required about as fast as we could sensibly absorb them.

Senator STENNIS. You anticipate any trouble in the next few months or the next year?

Dr. GLENNAN. I think not, and largely because this is the present glamour field in the fields of science and technology. People are attracted to it as they were to the atomic energy field 10 years ago.

Senator STENNIS. I have exhausted my time.

Senator Wiley, we are glad to have you here. Before you came in, we agreed to the 5-minute rule that would go around the table.

Senator WILEY. I would like to have someone show me the inner workings of that satellite.

Senator STENNIS. Excuse me, Senator Wiley, but Senator Smith do you yield to the Senator from Wisconsin?

Senator SMITH. Yes, Mr. Chairman, I yield.

Senator STENNIS. Senator Smith yields to Senator Wiley.

VANGUARD INSTRUMENTATION AND THRUST

Senator WILEY. I would like to have someone show me where this sphere was on the Vanguard.

Dr. SILVERSTEIN. Right here, sir. This is the sphere that you see here, the upper stage. This rocket was attached. This rocket weighs about 50 pounds—this sphere about 21 pounds and both went into orbit.

Senator WILEY. That is a very good explanation. It satisfies my curiosity. Now how did it get rid of the sphere?

Dr. SILVERSTEIN. It exploded off.

Senator WILEY. Blows off?

Dr. SILVERSTEIN. Yes, discharged out.

Senator WILEY. Now will you explain from the bottom how you got the thrust?

Dr. SILVERSTEIN. This is the first-stage rocket. It is 28,000 pounds of thrust.

Senator WILEY. Yes.

Dr. SILVERSTEIN. And it lifts the rocket off the launching pad and takes it up to the atmosphere and burns all the fuel out of this first tank, after which it cuts off.

After it cuts off, then the second stage comes out and here you see the second-stage rocket. This rocket has a thrust of about 7,500 pounds and has the fuel contained in this tank. It goes further out into space, turning around slowly as it goes out and after it burns out, it coasts and continues to coast until the rocket reaches a position horizontal with the earth's surface.

Senator WILEY. How far up?

Dr. SILVERSTEIN. In this case, it was 335 miles.

Senator WILEY. 335 miles?

Dr. SILVERSTEIN. Yes.

Senator WILEY. It is in orbit then?

Dr. SILVERSTEIN. It is in the orbit, but not the speed yet. It is in the final orbit, but it hasn't reached the speed.

This rocket then disengages and fires, and when it fires, it pushes the rocket up to final speed. In the meantime, of course, it is spinning. It has been spinning and the thrust of this rocket will be uniformly distributed around the axis. Then the body is gyroscoped too, after it is spun so it will maintain its position in space. Then, as soon as rocket is burned out, the firing ceases.

There are several small rockets here that disengage these two parts and spread them apart, and this then goes off into space by itself, and this one goes off traveling behind it, and they gradually separate at a rate of about 60 miles per day, both in orbit.

Now, with the orbital height of the satellite, it is expected to stay up many, many years.

Senator WILEY. Start from the ground now and tell us about the thrust of each stage. What power do you have?

Dr. SILVERSTEIN. The basic thrust was 28,000 pounds on this first stage rocket. The next stage rocket was the 7,500 pounds of thrust. The third stage rocket has, let's see—2,800 pounds of thrust, I think. I will have to recall this, sir—and then it fires. Then they separate and the satellite goes off into space.

Senator WILEY. What do you think the Kremlin has?

Senator STENNIS. Excuse me, but your time has expired.

Senator Young?

Senator YOUNG. May I say that I have been astonished by the testimony, and may I say, Dr. Glennan, you have made a most outstanding witness, one of the most outstanding that I have been privileged to hear.

FIRST GENERATION EXPERIMENTS

May I just ask one question which perhaps is along the line of the last question of Senator Wiley. You have mentioned in your statement that you are now in the first generation and I think you call this first generation, space experiment.

Now will you make a little explanation of that? I am interested to know in what generation of experiments do you estimate that the Soviet Union is in, if you have a term for it and if you are free to state that to us.

Dr. GLENNAN. Senator Young, I think the way I would answer that is that the first generation experiment as we term them, are the simplest of the experiments that we can make in outer space. We are attempting to gain the first bits of knowledge about radiation, about the atmosphere, whatever we may find out there.

A second generation experiment would be something that is more complicated and intended to get the additional information it becomes necessary to have if we are fully to understand the phenomenon that we are encountering.

With respect to the last part of your question, perhaps I ought to say too, that the first generation experiments are normally fairly small things. Our present booster capacity, the Juno II, the Vanguard—these send up relatively small payload packages weighing 30, 50, or 60 pounds, some such thing as this, limiting, of course, our ability to put a variety of experiments into one single shot.

I think it could be said that the Soviet Union is in the same general position as ours with respect to first generation experiments, except that their substantial greater booster capacity has allowed them to put in a substantially larger number of single experiments into one flight. Thus, they may have six or seven different experiments going on in a single flight.

Now we have done this to an extent, but not to the same extent as the Soviet Union.

Hugh, would you care to add to that?

Dr. DRYDEN. I think this is about as good a statement as you can make. The payload is a measure of what you can accomplish, whether you are talking about a load in orbit, load past the moon, or military mission of some kind. It is a rough measure of what you can do and we have a ways to go before we can equal our competition in this regard.

Senator YOUNG. But we may hope to get out of the first generation and equal the dictators sometime soon.

Dr. DRYDEN. We are presenting this in the program presentation.

TRANSFER OF ABMA

Senator YOUNG. Now along another line that is a little unclear to me. You stated on page 6 of your testimony, and you also amplified that in questioning, that "The Department of Defense felt unable to agree to the transfer." Then I believe you said that was going to be reexamined. Do I assume from that, Dr. Glennan, that you mean it is going to be reexamined by the Department of Defense?

Dr. GLENNAN. By the Department of Defense and ourselves, if we find it desirable to ask for this transfer again.

When this agreement between Secretary McElroy and myself was presented to the Space Council and to the President, it was agreed that the workings of the agreement, the results of the agreement, should be reexamined, reported to the President and the Space Council within a year or at such earlier time as I might desire to do this.

Senator YOUNG. But as I understand this, you feel at the present time that from your viewpoint a complete transfer is preferable?

DR. GLENNAN. I certainly do, sir.

Senator YOUNG. In other words you are hopeful and you don't need to reexamine the matter. You feel very confident it is what you want, and you are hoping that they will reexamine it and then be favorable to a transfer. Is that correct?

Dr. GLENNAN. I would rather put my viewpoint this way, Senator Young. I entered into that agreement in good faith and we are going to try our best to make it work and see if we can't avoid making the argument again. It is not a pleasant thing to get into an argument of this sort. We are going to try to make it work the best we can. If it does—fine. I think the Nation will be satisfied. If it doesn't, I will bring it up again.

Senator YOUNG. I hope you will. But has it been working somewhat satisfactorily?

Dr. GLENNAN. Yes.

Senator YOUNG. Thank you.

Senator STENNIS. Senator Martin?

MOTION OF VANGUARD SATELLITE IN SPACE

Senator MARTIN. Did I understand you to say that the final stage sets up a spinning motion on that instrument?

Dr. SILVERSTEIN. Yes, sir.

Senator MARTIN. There is no tumble?

Dr. SILVERSTEIN. The spinning motion is aimed to avoid the tumble.

Now in time, if there is energy absorption, there will be tumble if it stays up long enough.

Senator MARTIN. It will be impossible to keep the spinning up indefinitely, of course, I would imagine.

Dr. SILVERSTEIN. It will spin. Eventually it will turn in the axis so the spin is along the major axis, but it will start off and spin in the axis it is spinning now for a very long time.

Senator MARTIN. Does that help it in its flight to keep it spinning rather than to allow it to tumble?

Dr. SILVERSTEIN. This is very necessary for it to maintain its axis so these two infrared sources can see the earth on each revolution and so that you could know where they were because you have to spot these points on it later on, onto a map.

Senator MARTIN. Is the amount of thrust affected by the height of the projectile?

Dr. SILVERSTEIN. Yes, sir.

Senator MARTIN. Can you compute that accurately?

Dr. SILVERSTEIN. Yes, sir.

Senator MARTIN. Even up in space?

Dr. SILVERSTEIN. The thrust increases up to the point where the rocket is discharging basically into a vacuum because the upper atmosphere is a vacuum; it is somewhat proportional to the ratio of the pressure in the rocket chamber and the pressure outside. So there is more thrust out in the space, in the rocket, than at sea level.

APPRENTICESHIP TRAINING IN SPACE PROGRAMS

Senator MARTIN. Just one other question. You have quite a large staff. Do you have any preparation or any facilities for encouraging apprentices in this field, or do you take the finished product only?

Dr. GLENNAN. No, I would ask Dr. Dryden who managed this operation for many years to answer that, sir.

Senator MARTIN. I don't know what an apprentice is in this field myself.

Dr. DRYDEN. We do have apprentices in the trades. I assume you are not speaking of that. We, in general, get our staff fresh out of the universities and train them in the special fields in which we work. We do run training of junior people who come on our staff. We do have authority under the general legislation of the Congress to do a certain amount of training in summer schools and at universities.

We would regard a man who came out of college with an A.B. degree or engineering degree as an apprentice in the space job

Senator MARTIN. I would expect that.

Dr. DRYDEN. They don't teach this in school.

Senator MARTIN. My question is only headed in this direction—that as I visualize this program, we must give proper encouragement to prospective future leaders and can't wait until they are old to start with—and I wondered if you had that as part of your program. I will go along with you on any age you say is the apprentice age. A man may have a Ph. D. and still be an apprentice as far as I am concerned, but we do want to get them young, if we can possibly do it.

Dr. DRYDEN. A great majority of our staff come in at the junior level, young men, but we do get some older people along the way.

Senator MARTIN. Is this allowed for in your budget, this expansion and encouragement of young people before they are full-grown scientists?

Dr. DRYDEN. They come in, in the junior grades, and are trained and progress as they win experience.

Senator MARTIN. We are going to win this on the human level eventually, I believe.

Senator STENNIS. Thank you, Senator.

Senator Cannon?

VANGUARD SATELLITE

Senator CANNON. Doctor, this model here is just simply a cutaway for illustration, is it not?

Dr. GLENNAN. That is right.

Senator CANNON. The orbital vehicle itself is metal covered on the outside and closed, and with just the two photoelectric cells, the eyelets you speak of?

Dr. GLENNAN. That is right, and the antenna.

Senator CANNON. How long do you anticipate that your batteries will be good for the purpose of transmitting this picture?

Dr. GLENNAN. I would again ask Dr. Silverstein to reply.

Dr. SILVERSTEIN. The batteries for transmitting the picture are good for about 2 weeks.

The batteries for the transmission of the radio signals are good for about 4 weeks.

Senator CANNON. Now, on your guidance system, what part of the rocket itself is the guidance system?

Dr. SILVERSTEIN. It is located in the second stage right here and it controls, however, the first and the second.

Senator CANNON. And then is there a separate system that is employed when your orbital vehicle gets parallel to the earth so that your last rocket is put in an axis?

Dr. SILVERSTEIN. At that point, the spin of the rocket holds it along the path that it leaves the last stage. It is in orbit and in the right direction.

Senator CANNON. I see. Now the thrust of that last stage rocket you mentioned seemed to be rather low compared to the other rockets. Is that computed at sea level, or is that computed at the altitude where that rocket goes into action?

Dr. SILVERSTEIN. I can't answer that question now. I will put it in the record for you, but I don't remember just now. The thrust would be low. You see, on progressive multiple stage vehicles, the first rocket has the most thrust because it has to carry the entire weight. Then the next rocket has less thrust because now it only carries the weight that is left after you separate it from the first stage.

So progressively, as you go from a first, second, and third stage, the thrust of the rocket decreases.

(The information referred to is as follows:)

Thrust of Vanguard rocket (3d stage):	*Pounds*
Sea level	2,800
High altitude	3,100

SUPPLEMENTAL FUNDS REQUEST

Senator CANNON. Now, Doctor—to get back to the supplemental budget request—as I understand it, the $3,354,000 is brought about simply because of the bill relating to the addition in salaries?

Dr. GLENNAN. That is right.

Senator CANNON. The $20,750,000 Mercury project—was that not anticipated at the time of the last budget—or what is the situation?

Dr. GLENNAN. I think this has developed as we have come ahead with this program, sir, that we can make better time in the project by buying long leadtime items at the present time and pushing ahead with this amount of money.

We are asking for money which we can usefully use now.

Senator CANNON. Well, is that something that normally would have been included in the 1960 budget and perhaps is being pushed up to this supplemental now?

Dr. DRYDEN. If you recall, Senator, we had an estimate to begin this program last year and it was reduced in the amount of $45 million.

Senator STENNIS. If you will yield to me right there—with the understanding, was it not, that you gentlemen would come back in January if you needed extra money. I remember it was settled on that basis.

Senator CANNON. So it would have actually been covered in that first request.

Dr. GLENNAN. Yes, sir.

JET PROPULSION LABORATORY

Senator CANNON. Now with relation to your purchases—your procuring the JPL at San Bernardino and the acreage—I note that it is to protect you against encroaching building, apparently. I am wondering whether or not, if you acquire that, you are sufficiently protected for the development that you anticipate making in the future, or if you are going to be coming back in a few years and saying "now we have outgrown our area and have to move out in the wild some place where we won't be in everybody's hair."

Dr. DRYDEN. The jet propulsion laboratory is the birthplace of rocket propulsion in this country. It was started at a time when this was not a very reputable business to be in. Some professors and students at the California Institute of Technology started this kind of experiment, and from this same group came the Aero-Jet Co. and the first jet-assisted rockets for takeoff.

Now this laboratory has grown from that small beginning with propellants with a relatively low performance, and starting with rockets with relatively low thrust. Through the years, they have not done any major relocation. The propellants have become more powerful. They have had to make experiments on larger rockets.

The result has been that there has been a waiver of the code of safety standards. In other words, you have been going just a little beyond the safe practice on distance between adjoining test stands and this kind of thing.

Now the situation is that it would cost a very large sum of money to try to tear down existing structures and rebuild the laboratory on its present site. It is much cheaper to buy the adjoining land to start your test stands with the safe distances and with the modern safety precautions on this new plot of ground than it is to try to rip down all the old and replace it.

Now the laboratory will be interested in experiments which cannot be carried out on this site, and we do have in our 1960 budget submission, money for propulsion facilities on hazardous types of fuels which would serve both the JPL and the work which the old NACA has been doing in another location, but this is a simple case of instead of tearing down the old house and rebuilding on the same site, it is much cheaper to go over to the adjoining ground and to get the proper safety distances built in.

Senator STENNIS. Senator Smith?

SPACE PROGRAM EXPENDITURES

Senator SMITH. Dr. Glennan, how much money is being devoted to space programs during the current year by all Government agencies?

Dr. DRYDEN. We have a total of $200 million in addition to the $100 million in the old NACA; $300 million in NASA.

Dr. GLENNAN. I think if I could take just a little time I have it here.

Dr. DRYDEN. As I recall it, it is in the order of $450 million to $500 million as compared to $800 million in the 1960 budget.

Senator SMITH. That is the current 1960 budget?

Dr. DRYDEN. Yes.

Senator SMITH. Will you put the accurate figure in the record?

Dr. DRYDEN. Yes.

(The information referred to is as follows:)

Space budget totals

[In millions]

	Appropriated, 1959	Pending 1959 supplemental	Total, 1959	Budget, 1960
NASA	$208.1	$45.0	$253.1	$368.2
DOD (ARPA)	344.1		344.1	307.0
AEC	36.8		36.8	32.4
Total	588.0	45.0	634.0	70 .6

NOTE.—Above data excludes the costs of the NACA laboratories and related construction. It is estimated, however, that between 50 and 60 percent of the effort of these laboratories is related to research significant to the space mission. The budget for these laboratories and related construction totals $130,900,000 in 1959 and $117,100,000 in 1960.

Senator SMITH. Dr. Glennan, when Mr. Roy Johnson, Director of the Advanced Research Projects Agency, appeared before this committee and the Preparedness Investigating Subcommittee on January 30, he gave the following testimony: "Mr. Johnson, I believe in fiscal year 1959 there should be a supplemental appropriation."

We have asked the Secretary of Defense, in ARPA, for some $40 million supplemental funds to pursue the big booster. We have asked for more money for early warning satellites and for another classified program that the Joint Chiefs of Staff have proposed to us just recently.

The new civilian agency and ourselves have discussed other funding that is needed in 1959. In other words, I believe that something in the order of $150 million more money is needed in fiscal year 1959 and that the same amount of money is needed, perhaps a little more, in fiscal year 1960.

Do you agree with Mr. Johnson that additional supplemental funds are going to be required?

Dr. GLENNAN. I am not as certain as Mr. Johnson was that additional supplemental funds were going to be required. We are developing our program along what I consider to be sound lines.

I would say that I am reasonably certain actually that we may require additional funds. Indeed, we have had this under consideration.

Senator SMITH. Then that is what is being done on Mr. Johnson's recommendation. You say that you are at present considering further supplemental funds?

Dr. GLENNAN. That is right.

Senator SMITH. To carry out his recommendations?

Dr. GLENNAN. Not to carry out his recommendations, but to carry out our own program.

Senator SMITH. What are the additional funding requirements for space programs that Mr. Johnson discussed with you?

Dr. GLENNAN. This has to do almost entirely with booster development and with tracking station additions. The stations which track the satellites and acquire the data which is sent back from them by telemetry.

CLUSTER BOOSTERS

Senator SMITH. Dr. von Braun and Mr. Johnson both testified that the 1.5 million pound thrust clustered booster could be speeded up if an additional $40 million were made available in 1959. Is this being done?

Dr. GLENNAN. This is a program that is funded by the ARPA Division of the Defense Department, and I understand that they have made a request for additional funds, and as I recall I think they have reprogramed $10 million or $12 million to ABMA on this already.

FUTURE SPACE PROGRAM

Senator SMITH. Doctor, what general funding level do you visualize for space programs in the 5-year period starting with the fiscal year 1961?

Dr. GLENNAN. I have said in my written testimony that I think this is the last year we will be asking for as little as a half-billion dollars.

To try to go beyond this is really crystal balling, but I would not be surprised to find within, say, 2 years that we might be asking for $1 billion in this program.

Our own viewpoint on that is that there will be a general level, if you will, of underlying space science investigations which will be funded year after year at a level-of-effort rate.

What this will be, I can't tell you now, but when one erects on top of that base specific programs, such as the booster program I have suggested, it might cost as much as $2 billion in the next 6 or 8 years.

When one erects further such things as the man-in-space program which to make our first orbital flight with a man, that probably will involve $200 million, so that one can see that this is apt to be an increasing program.

Senator SMITH. Thank you. I have other questions, Mr. Chairman, but I will await my next turn.

Senator STENNIS. All right, Senator. I have a further, brief question. You mentioned a billion dollars there as a possible figure.

Now, you have jurisdiction over all new space programs; do you not?

Dr. GLENNAN. Only civilian space programs.

Senator STENNIS. So your $1 billion is only for civilian programs?

Dr. GLENNAN. That is right, sir, but I would like to point out that the bulk of the responsibility for the new boosters required particularly for space programs, whether they are military or civilian, are funded and directed by NASA.

Senator STENNIS. Yes. And in that way you are going to have a part of the program involving military applications; are you not?

Dr. GLENNAN. Yes. The military will utilize the results of our expenditures without any question.

Senator STENNIS. Well, I thought in these new programs you now mention, the boosters and such, that you were going to have the initial part of those programs up to a certain stage, and then you divert it over to the military. Is that right?

Dr. GLENNAN. That is essentially right. My viewpoint on this kind of activity, sir, is that NASA, as required by the law and as set out in the law, is a research and development agency. Our task is to take the first steps or to develop the new knowledge and the new techniques, and when they become possible of operational application, this is a matter that we then turn over to a civilian organization or the military.

Senator STENNIS. That is the way I remember the law, as passed, that you took the initial part and then it branched off. If it proved practicable, it passed either to the military or to a civilian organization, or perhaps both.

Dr. GLENNAN. That is right.

Senator STENNIS. And when you speak of the $1 billion, then, you are speaking about civilian and military—as far as you go in the program?

Dr. GLENNAN. That is right, sir.

Senator STENNIS. All right. Now, Senator Young and I were discussing here across the table the point raised about your tracking facilities. I am going to leave that part to Senator Young, if I may.

DUPLICATION OF FACILITIES

I want to ask you about the duplication now. I have seen the development of all these programs and warning systems and so forth, and both the Department of Defense and you now have certain tracking facilities in operation. Isn't that correct?

Dr. GLENNAN. That is right, sir.

Senator STENNIS. Now, what about the duplication, if any, between them and what you are trying to do and what you are trying to avoid in the future?

Dr. GLENNAN. We have been very conscious of the possibility of duplication of facilities of this kind, the tracking networks springing up all over the country as a matter of fact, and in a variety of agencies.

I think it was January 10 that we had a meeting with the Defense Department following studies which had been made by the jet propulsion laboratory under contract to ARPA, and by our own staff—these two studies being put together.

What we have done is try and develop the beginnings of a national research and development tracking program. We have agreed that certain of the stations will be funded and operated by ARPA and they will track for us and secure data for us.

Conversely, we will build some of them, manage them, get our own data as well as the DOD. As there gets to be a colony of these things in outer space and any of these particular stations begin to get overloaded, then additional equipment may be placed on that particular site and in that instance, if it were a site managed by us, the DOD would fund the additional equipment that went in there, but the communications will be existing communications. Usually, these are military communication circuits which will be used jointly by all of us.

There won't be duplication of that sort, and the logistics of that sort will be common logistics for all of us. We are quite conscious of this problem.

I should point out, however, that we are talking largely about research and development and as we move into the operational system, let's say that the military develop a communications system which is important in their communications setup, worldwide, using satellities.

They would undoubtedly then have their own tracking stations limited in its use to that communication channel, you see? That is when it becomes an operational system.

Senator STENNIS. After becoming operational you think they will have to be separate?

Dr. GLENNAN. Then we would expect they would have to be separate; yes. That becomes a routine operation while ours is a research and development operation where the individual experimenter may have to make some slight change in the equipment because it is an experiment, not at operational system.

Senator STENNIS. I believe my time is up. Senator Wiley?

Senator WILEY. I wonder if we could have an analysis filed with the committee showing the cost of the Vanguard satellite.

Dr. GLENNAN. We will be glad to get it and place it in the record.

Senator WILEY. Then an analysis showing the salaries that are paid.

I made a speech today on the floor of the Senate in relation to inflation and if we could find out in this great experiment where we could save a little money, why I think we had better save it. That is, if it isn't to the detriment of the program.

Dr. GLENNAN. We will be glad to file that with the committee.

(The information referred to is as follows:)

Vanguard program

Total cost (in millions)	$97
Cost per Vanguard (vehicle plus firing)	$3.5
Personnel, Vanguard Division of National Aeronautics and Space Administration (authorized strength)	161
Per annum salary cost (in millions)	$1,242,000

Senator WILEY. Have you any ideas where you could save some money?

Dr. GLENNAN. We are a baby industry, and I would be misleading you completely if I were to say to you that we could do this, in my opinion, at less cost than we are presently doing it.

If you are speaking about the efficiency of the operation, how can we save money to get more done with the same amount of money, I think we are, at that, reasonably consistent, with that objective.

Senator WILEY. Well, there are two ways of busting the country—one, let the Russians bust us, and two, bust it ourselves.

Dr. GLENNAN. Right, sir.

Senator WILEY. With the 40 million bondholders and the 120 million insurance policyholders, there are a lot of old foks living on annuities—folks who thought they had a little income built up find out that they are not in such good shape as they throught they were—and my questions aren't impertinent. My question is concerned simply with the idea of trying to find out how we can save money.

Dr. GLENNAN. I understand, sir.

Senator WILEY. And whether every dollar brings a dollar's worth of return.

Dr. GLENNAN. Right.

Senator STENNIS. Thank you, Senator Wiley.

Senator Young?

Senator YOUNG. Of course, I suppose it is a fair statement to say that we fear we may be in worse shape if we don't go ahead and progress and try to grow up in this endeavor. That leads me to this question—isn't it reasonable to expect that if we continue this and until we reach the next growing up stage, it is bound to be more expensive than the current project?

Dr. GLENNAN. I would agree, yes. I think I would say it is bound to be more expensive.

Senator YOUNG. And as time goes on, it is highly essential that you do everything possible to avoid duplication, isn't that correct?

Dr. GLENNAN. I think that is quite true, and I took Senator Wiley's question to be the sort of question that one has to answer by saying we must use prudent management methods so as to get the maximum value out of every dollar we spend.

Senator YOUNG. What are the facts, however, Dr. Glennan? Has there not been considerable duplication in the experiment and in the development package, now that you are becoming well-established, that you are now going to try to avoid?

Dr. GLENNAN. I think that is quite right, sir.

Senator YOUNG. Is that a fair statement?

Dr. GLENNAN. Yes, sir.

MINITRACK SYSTEM

Senator YOUNG. I would like a little more information as to what the minitracking system is. I think I may know in general, but I would like to have it outlined in greater detail.

Dr. DRYDEN. I don't know that we have a real, electronic expert here today. I am afraid I don't know the exact source of the name. The minitrack system is what is called a radio interferometer. It consists of a station with four large antennas and signals received at

these four antennas are intercompared so that they measure angular direction of the satellite.

Now I don't think we have an electronics man with us today. Does anyone want to volunteer? Mr. Rosen?

Senator, this is Mr. Rosen.

Mr. ROSEN. The word "minitrack" is derived from the miniature nature of the transmitter in the satellite which weighs less than a pound and it is continuously sending out a radio signal that is picked up by receivers on the ground, and these receivers measure the direction of the satellite in space.

In essence, they draw a line from the ground to the satellite in space and thereby tell you where it is.

ELIMINATING DUPLICATION

Senator YOUNG. May I ask Dr. Glennan to come back to a very important subject again? Do you feel you are encountering as much success as you have been hoping for in your efforts to avoid this potentially tremendous military and civilian duplication in the experimental and developmental stage?

Shouldn't it really be taken over by one or the other in its entirety?

Dr. GLENNAN. Senator Young, I think we are just a little bit too new in the business to be completely sure about that.

I think there are pros and cons and I probably could debate both sides of this. There is very little that one can conceive of in this field that doesn't have both the civilian and a military interest. One would get into the philosophies of method of approach to research problems that might be followed by the military versus the civilian group, and that type of thing.

I think what we have done and what is required in the law, is to try to separate, sensibly, those items which have now a military requirement behind them as determined by the Defense Department, and the Department of Defense carries those out.

Many of their activities have been transferred to NASA and, indeed, more of them are in process of being transferred, such as the meteorological satellite activities where there was not duplication, but certainly they were doing the job in meteorology and we were; and it seems best to have that under single management and, indeed, that is going to be done as of July 1, and we were negotiating about it yesterday.

Now, the interrelationships of these two agencies, ARPA and NASA, I think, are going along very well at the present time. I think we need more time to determine whether it would be really beneficial to take it all out of one or put it all into one agency.

Senator YOUNG. Could it be put in a joint agency—joint civil and military? Could that be the answer to save money and get the maximum results?

Dr. GLENNAN. I doubt that this would really be effective, but you are asking me a question I would have to analyze very thoroughly, but I doubt that would be effective.

Senator YOUNG. That is all.

Senator STENNIS. Your time is up.

Senator Martin.

ADDITIONAL REQUESTS FOR FUNDS NOT ANTICIPATED FOR FISCAL YEAR 1959

Senator MARTIN. Doctor, the bill we have before us is S. 1096, and calls for authorization of $48,354,000. That is, of course, in addition to any previous authorized funds for your use for this fiscal year.

Dr. GLENNAN. That is right.

Senator MARTIN. And do you anticipate any other requests between now and the end of the fiscal year?

Dr. GLENNAN. I do not, sir.

Senator STENNIS. If the Senator will yield right here, the Chair understood the doctor to say a minute ago, as did Senator Martin, that he had something else in mind in fiscal 1959. Did we misunderstand you?

Dr. GLENNAN. I think you did. I said we were discussing this and I suspect if we have something it will probably be 1960 before we get to it.

Senator MARTIN. That is why I asked this question, because I wanted to keep myself oriented on what we are doing.

Dr. GLENNAN. I do, too, sir.

Senator STENNIS. All right.

Senator Cannon.

NO NASA DUPLICATION WITH ABMA

Senator CANNON. Thank you, Mr. Chairman.

Doctor, this is following along the line of Senator Young's questioning, and you may have answered it in part, but I would like to ask you specifically whether or not in your opinion there is a duplication between ABMA and the work that NASA is doing at this time.

Dr. GLENNAN. I think not, sir.

Senator CANNON. There would be no duplication there, so that the consolidation or turning ABMA over to NASA would not result in economies?

Dr. GLENNAN. Would you state that last again, sir?

Senator CANNON. Would the turning of ABMA over to NASA result in economies, in your opinion?

Dr. GLENNAN. In the long run, this is apt to be the case, one would think, because if we find it necessary, and I would guess only if we should find it necessary to build our own staff, then either there must be enough work to keep our staff going and their staff going, or there would be duplication, and the duplication would result simply because of that.

At the present time they are working for us, they are under contract for us. Some $20 million, I think, is presently under contract down there, and I think that the program thus far developed for next year is about $20 million.

Senator CANNON. But part of their programing on their own would not include some of the work you are doing on your own?

Dr. GLENNAN. No, I think not, sir.

MANNED SPACE FLIGHT

Senator CANNON. Now, Doctor, I know that many people in the Nation today are going to become more vitally concerned about this space program, particularly when they hear of the fact that in the

very near future you no doubt will be requesting somewhere in the neighborhood of a billion dollars a year in funds from our national budget for the purpose of carrying out the program.

In the light of that, I wonder if you would care to comment on the importance of sending a man to the moon, or putting these objects into orbit, or sending a man into outer space and bringing him back. Just a brief comment, if you will, please, in the light of a billion dollars a year expenditure for the program.

Dr. GLENNAN. This is a question, Senator Cannon, that I suppose could be answered a great many ways by different people.

Man has always been curious about his environment, and his natural curiosity is going to carry this program forward, I think, without any question. Whether it will be carried forward at the pace that it has been carried forward is quite another question.

Here we find ourselves in competition with another nation that is really forcing our hand to a considerable extent, that is at least as to the manner and the pace at which we go about it.

The things that we expect to find in those areas, which thus far have been identified as possibly to be of use commercially or in a military sense, such as the weather forecasting business, many people, have estimated that these would pay many times over the cost of the programs on which we are embarking.

Communication is the same way. Indeed, the only way in which we will be able to handle communications in the future may be through satellite channels.

The return in general scientific information is never possible of pricing, but throughout the time that we have been pursuing scientific investigations of this sort, we have always found that there was a payoff at some point along the line.

Would you care to add something to this, Hugh?

Dr. DRYDEN. It might be helpful to consider the past experience with the airplane. We are at about the same stage in space technology as we were at the time of the Wright brothers in aeronautics. We in this country allowed the airplane to be taken and developed in Europe, so that when the First World War came along, we had to buy our airplanes over there. Only then did we wake up to the importance of supporting the development of the airplane. It was at that time that the old NACA was established.

Now this is the situation that we are in with respect to space. We cannot demonstrate to a banker that this is good security on his loan by anything more than faith, that in going into a new, completely new field of this kind, that there are bound to be results of great value, both civilian and military. I think that we cannot disregard the military implications, even though we do not see them clearly right now.

We have mentioned some possible commercial applications. We think, as a matter of faith again, that we are going to have men going out into space and the sooner we start to study the problems the sooner we are going to be in position to consider such activities.

Now the difference is that there is another set of zeros on the costs. This is expensive; it is a game that only big nations can play. In fact, only two nations in the world today are in a position to support this kind of a program, and I feel, as many others do, that if we are

not willing to do it, there is a nation that is going to do it, whether we do it or not.

Senator Smith.

FOREIGN INSTALLATIONS

Senator SMITH. Dr. Glennan, on page 10 of your statement you refer to the extension of the minitrack electronic tracking system to Alaska, Newfoundland, Europe, continental United States, and so forth.

Also, you refer to installations of radar dishes in Australia and South Africa.

What will be the condition of these stations on foreign soil? Will negotiations or agreements be necessary in these developments?

Dr. DRYDEN. Yes, there have already been negotiations. If you recall, the IGY made agreements with South American and other countries for the minitrack stations which we have taken over. In a great many cases we are able to do a cooperative task in which the local people undertake the operation, that is, we supply the capital investment and the local people do the operations.

Now, since all of the agreements in these cases have not been completed, I don't think we can discuss them all in detail. In South America we have completed some arrangements by which a university accepts a contract to supply scientists to operate a station in their country.

Senator SMITH. Do you anticipate any problems, any great problems or difficulties?

Dr. DRYDEN. We do not. There is great interest, especially in the fact that we are dealing with civilian scientific programs, a continuation of the IGY type of cooperation. We anticipate no difficulties.

NEED FOR CENTRAL COORDINATION OF DATA COLLECTED

Senator SMITH. Dr. Glennan, you have mentioned the necessity for bringing back to a central distribution point the records collected by the worldwide network of tracking stations.

In view of the point of the variety, what are you doing about the coordinating, the collecting, the collating, and the analyzing of all of this?

Dr. GLENNAN. This is going to be a very real task, actually, because in some of these experiments we get many miles of tape.

The problem is under study at the present time in our organization, how can one perhaps use sampling techniques so that one doesn't have to look at every foot of these tapes.

What we are proposing is to move the Vanguard center, which you find on Pennsylvania Avenue as you drive toward the White House, to Beltsville and expand it somewhat so that it becomes the central coordinating point for the research and development activity of this kind. There one will bring this data together, and make copies of it to send to other centers. Let's say that the University of Iowa, where Dr. Van Allen has his work done, may have a computing center where we can send the tapes. He can have the data reduced and analyzed by his staff there.

Does that answer your question?

Senator SMITH. Yes, but I am troubled a little bit about the useful application of it.

Do you have hopes of getting to the point where it is so efficient that you can get the best use of such data?

Dr. GLENNAN. I think we must do that.

Senator SMITH. Yes, I think you must, too, but do you?

Dr. GLENNAN. Certainly I hope that, Senator.

Senator SMITH. Do you see the possibility?

Dr. GLENNAN. Yes, ma'am, I do.

Senator SMITH. Thank you, Mr. Chairman.

Senator STENNIS. Members of the committee, Dr. Glennan has to leave; he wanted to leave in connection with some other matters as soon as he could, and we cannot finish this afternoon, anyway. So could we excuse Dr. Glennan now, and call on Dr. Dryden for his opening statement?

Dr. Dryden is the former Director of the National Advisory Committee for Aeronautics, a most reputable organization. I remember him most favorably from being here in previous years.

Could we excuse Dr. Glennan now, and ask Dr. Dryden to give his opening statement, and then we will take a recess at 4:30, since we have to come back, anyway.

Dr. Glennan, thank you very much, and you come back in the morning. We do have further questions for you, if you can return in the morning at 10:30.

Dr. GLENNAN. I shall be here.

Senator STENNIS. Thank you very much.

Dr. Dryden, we are especially glad to have you here today. We remember you very pleasantly, sir, from former experiences with you, and we are glad to see that you are still in harness, and we would be very glad to hear you on your statement now.

Do you wish to read your statement or put it in the record and comment on it—whichever you wish.

Dr. DRYDEN. Mr. Chairman, I have no formal written statement to present. I want to merely introduce presentations of details of our program.

I would, however, like to remind you that the National Aeronautics and Space Act did transfer all of the functions of the National Advisory Committee to the new agency.

Now, in our presentations we have had this take second place, not because we feel that work in aeronautics is unimportant, but because you are concerned especially in the bill that is before you and in fact with the larger fraction of the moneys, with space.

There is one presentation by Mr. Abbott at the end of this program which will have to be given in closed session, because it deals with classified military matters on advanced aircraft, the new bombers, and so on.

This is the part in our formal presentation which relates to the aeronautical work of the former NACA.

We have a series of presentations on the major aspects of the space program. I think we have time to get one of these in——

Senator STENNIS. All right.

Dr. DRYDEN. Which is the one on advanced technology, the booster program and related problems by Dr. Silverstein.

Senator STENNIS. We are very glad, indeed, to have you here, sir, and you just proceed in your own way, if you will. We don't want to

rush you, but I think we will have time to have you make your opening statement, at least, and maybe a few questions.

Dr. SILVERSTEIN. Thank you, Mr. Chairman.

Senator STENNIS. All questions will be friendly questions, of course.

TESTIMONY OF DR. ABE SILVERSTEIN, DIRECTOR OF SPACE FLIGHT DEVELOPMENT, NASA

Dr. SILVERSTEIN. I have a chart presentation, and it deals with the subject that has been discussed by Dr. Glennan in his opening remarks, with this very important booster program that needs to be carried on to provide this country with the increased capability for putting into space the loads that we visualize in the years ahead will be required.

Now, in this program, most of the important items have long leadtimes and whereas now we are carrying on a program utilizing existing equipment, we see the need to start at this early date the longer range booster systems which we see very clearly will be needed in the future.

EXISTING VEHICLES

Before I show you the elements of the program, very briefly I would like to relate the history of our booster developments of the past few years. You will recall that in 1955 the President authorized the launching of a satellite in this country under IGY, and this was called Vanguard. We talked about it earlier and showed the model.

This satellite was designed and the construction phase was carried along. However, it was not until on October 4, 1957, as you will recall, when the Russians launched the sputnik, that there was in fact a very marked increase in the tempo of our whole thinking about space, and it lead to the early flight in January 31 of the first of the Explorer vehicles.

Now, the vehicles we are using, except for the Vanguard, which was conceived as a space vehicle, have been put together from missile parts and other parts not as specifically designed space vehicles, but rather as ad hoc vehicles to do a job.

In the 5 months that we have been in operation, we have been very diligently applying ourselves to the task of trying to construct what is in truth a space vehicle program, and in this work we have been bringing in the leading experts in the country in the propulsion and the booster fields.

We have worked closely with the Department of Defense in constructing the whole program.

The boosters that we currently have, and I think you will recognize them from their names, are first, this Vanguard vehicle which I show here. (Chart references apply to chart series 1 in appendix.)

JUPITER C

Next, the Jupiter C vehicle, which is made up of the Army Redstone missile with some solid rockets that are carried in a can on top. There are 15 small rockets, 6 inches in diameter, that are placed in this can and it is spun and they fire successively. First 11 of them fire in the second stage, then 3 of them fire in the third stage, and in the last stage is 1 of them.

On top of that we put the satellite that is fired into space. This is the Jupiter–C.

JUNO II

This is the Juno II. It was about the same configuration as Jupiter–C, except in place of the Redstone booster, we used the Jupiter booster here, which is the IRBM which was built by the Army Ballistic Missile Agency.

It has again the same solid rockets as the top stages, and it is a four-stage vehicle, and fires successively the 11, the 3 and the single solid rockets.

THOR ABLE

Here we have a Thor Able vehicle. This again was a vehicle put together to do a job.

Initially it was called an RTV, a research test vehicle, and was to test nose cones and has been used for this purpose, but it was also able because of the velocities that could be reached on the last stage, to put a satellite in space, and so it was used for this purpose.

This is made up of the Thor IRBM, and on top of that they took the last two stages of the Vanguard and mounted them on top of the Thor, and so we have a Thor Able.

These are existing vehicles. I think you could call them perhaps not unfairly, jury rigged, except for the Vanguard which started earliest and was designed from the beginning.

I don't want to condemn this group of boosters, for, in fact, during the last year they have performed remarkably well. This group has put six satellites into orbit, and we have put two space probes, one up to an altitude of 71,000 miles, and another 63,000 miles.

This is the 71,000-mile vehicle; this is the 63,000-mile vehicle.

However, the loads they can carry are small, and are limited to perhaps a maximum in this case of, say, 150 to 200 pounds, in orbit, and much more with these vehicles, down around to 20 to 30 pounds corresponding 20 pounds here, up to about 60 pounds here.

VEHICLES SOON AVAILABLE

Now, these loads are below the weights that are needed in the program we see almost immediately ahead. Our scientific people and others say we need bigger vehicles. There are a group of vehicles coming along.

THOR HUSTLER

I will start here. This is the Thor Hustler. This vehicle is made up again of the Thor booster, IRBM booster, and on top of it is the Hustler stage. Now, this Hustler stage initially was a stage that was to be used with the B–58 bomber, and underneath it there was a rocket-powered package. The engine was developed for that purpose.

However, when the need arose it was adapted for use with the Thor IRBM and the combination was put together to form a missile.

This was the vehicle that will be used in the Discoverer satellite which will be fired shortly by the Department of Defense. There are a series of these scheduled.

ATLAS ABLE

Now we come to the first multistage vehicle, soon available, in which we use the Atlas as the basic vehicle.

Now, you will recall we have fired an ICBM alone without a second-stage vehicle for the Score satellite which orbited around Christmas time of last year. If we take the Vanguard second stage and third stage, and put then on top of the Atlas, we call it the Atlas Able. This will carry larger loads into space.

Senator STENNIS. Carry what?

Dr. SILVERSTEIN. It will carry larger loads into space.

Senator STENNIS. Yes.

ATLAS HUSTLER

Dr. SILVERSTEIN. We can take the Hustler engine and put it on top of the Atlas, and with this vehicle, in some orbits you can carry, a load of 3,000 pounds. This vehicle will soon be available for use in this country.

But now, I pointed out all of these vehicles, these three, and the ones on the preceding chart basically are combinations of various rockets that have been put together to achieve a particular task. They have not been designed from the very beginning as space vehicles.

SCOUT

Here we have a vehicle that I think meets the requirements of most of us, in that it is hoped that it can be both economical and reliable. It is composed of a serious of solid rockets, and from our previous experience with solid rockets, we know that they are quite reliable. It is economical in that it is hoped that the cost can be about a fifth as much as that of the more complicated systems that you saw on the previous chart.

So we are going ahead currently building what we hope will be a much less expensive and much more reliable vehicle to take the place of these vehicles shown on the first chart, since it will carry about 150 pounds of load into a 300-mile orbit, and will satisfy many of the needs of our scientific program.

ADVANCED BOOSTERS

Now, I come to the beginning of what we call our advanced booster systems.

These are the vehicles that we are planning for the near future, and some for later use.

On this chart of advanced boosters, I show two vehicles. One is shorter than the other. The one on this side we call the Vega; the one on this side we call the Centaur. This vehicle again is based on the use of the Atlas ICBM as the first stage. The Atlas has demonstrated in the last year a remarkable reliability. It is a good building block to use for getting increased capability.

But on top of it, we have designed a second stage that matches the booster stage and have put on that a third stage.

These two stages are new stages. In this stage, however, we are using an existing rocket, which is the rocket I showed powered the

first stage of the Vanguard. We have that now and therefore only have to build the new tanks to match the Atlas, and the new guidance system.

For the top stage we currently have under contract and actually are in progress of manufacturing a new third stage using storable propellants. This work is being done by the jet propulsion laboratory. By storable propellants we mean propellants that are liquid at room temperature, and the reason we are interested in storage propellants for the third stage is because some of these third stages will have to coast out into space and be fired or ignited after a considerable period of time. We want a propellant combination that will remain stable during this coast period.

You will recall, of course, that the liquid oxygen, being a liquid only when it is at minus 235 degrees Fahrenheit, needs a great deal of insulation to hold it in a storable condition for a long time period.

Now, this vehicle is called the Vega. A sister vehicle here is the Centaur, and differs from this Vega in the sense that for this second stage we use a high energy propellant.

This is the first use in the space program of hydrogen which, because of the fact that it has about three times the energy content, say, of the kerosene used here, provides us greatly increased capability when we try to put a probe into outer space, such as in a mission to Mars or Venus.

You will note that the stage is taller because one of the characteristics of liquid hydrogen stored here is that it has about a tenth of the density of kerosene. The stage does not get 10 times bigger because of the higher energy content of the fuel.

Again we use the same rocket on top of the third stage, the storable propellant rocket that we used for the Vega.

The concept of our booster development program in line with our desire for economy and in line with our desire for a rapid accomplishment of the program, is this:

We have sought to keep down the number of new developments to a minimum, and to use, when we can, rockets and elements of rockets that exist and that match the requirements of the program.

You will see repeatedly in all the whole booster stages the same engines.

MILLION POUND CLUSTER

Going beyond this set of boosters in the national program two additional booster systems are in progress. We talked earlier about this work at ABMA, and this program for a million pound cluster rocket that is being sponsored there by the Department of Defense through the Advanced Research Projects Agency.

This booster is manufactured from engines that are the same as are being used in our current ICBM and IRBM vehicles. They are clustered in a group, with the tanks above them, and together they provide a thrust of a million or somewhat over a million pounds of thrust.

Above them we put a second stage which is a modified Titan or other ICBM missile modified to fly as a second rather than as a first stage.

Above that we put a rocket which is the same rocket we developed previously for the Centaur program, and then above that we have

again the same storable rocket. So you see as we move up to the larger size vehicles we utilize the same basic components.

SIX MILLION POUND CLUSTER

Next, we come to what is the largest of the current boosters that we have in our program.

It is a booster system which we hope will provide 6 million pounds of thrust, and it is made by clustering rockets that have a million to a million and a half pounds of thrust.

Now these rockets are already under contract with the Rocketdyne Co. The contract was entered into about the first of the year. It is very clear that as we try to carry on advanced missions that we will need vehicles with this thrust.

You see, we have added above this basic clustered booster stage of 6 million pounds thrust a second stage using one of the million pound thrust rockets. Above as a third stage we place a booster stage which was developed for the previous vehicle.

The number of these stages that we will use in any particular vehicle will depend upon the mission. If we are going deep into space and attempt to return, we will use more stages. If we simply are firing out into space, we will use fewer.

NEW ENGINE DEVELOPMENT

You might ask does this array of boosters do the job for us as far as we can see into the future. I am afraid I must say that they won't.

There will come a time when we will need larger boosters and new types of boosters.

An interesting thing about the booster family I have described is that there are only five new engines to be developed for all the configurations. We need to develop this 6,000 pound storable engine, which we already have under contract. We need a 15,000 pound Lox hydrogen engine, which we have under contract. A 20,000 pound storable engine, which is being studied. An 80,000 pound Lox hydrogen engine, which has been under research and development contract for the past year, and this million and a half pound Lox kerosene rocket which we have under contract.

So you can see the program is moving quite rapidly, and we are aiming to get our capability geared for the future.

Senator SMITH. Mr. Chairman, may I ask right there, when you say "under contract," do you mean you are actually producing except in the Research and Development?

Dr. SILVERSTEIN. Except for the Research and Development contracts, we have a contract for engines development.

I mentioned the lead time required for the million pound engine. We contract for it now because we realize that it will take about 4 years to get this engine through its development period.

Now to show the capability of this family of boosters, I have some charts here that show what they will do in the way of carrying load into different orbits and to different distances.

PAYLOAD GROWTH FOR 300-MILE ORBIT

For example, the 300-mile satellite orbit is a typical mission of interest in both the scientific program and for manned flight. This orbit will provide a great deal of information of use in the program.

This chart shows the payloads available from the existing boosters to be about 100 pounds.

We find with the new combinations soon to be available——

Senator STENNIS. Pardon me just a minute. You say that 100 pounds is the limit now on payload?

Dr. SILVERSTEIN. This is a round number. It is 100 to 150. It depends on exactly what orbit you put it in and the configuration. This is the order of the load that can be carried.

Senator STENNIS. The Vanguard payload is 21½ pounds.

Dr. SILVERSTEIN. Yes, but some of the other configurations will carry more.

Senator STENNIS. Yes, but you could go to around 150 in some cases. All right, proceed.

Dr. SILVERSTEIN. Soon to be available is 2,000, and there are some configurations where we can carry as much as a 3,000-pound load into the 300-mile orbit. These are all given in round numbers.

Now, with the Vega and Centaur stages which I showed you on one of the charts, the two based on the Atlas, we expect to carry a load of as high as 7,400 to 7,500 pounds into orbit. And our hope is that this development can move quite rapidly.

This is about the capability of the vehicles the Russians used in the lunik.

As we move along to the rocket being developed at ABMA, the clustered rocket, you see we have a capability of 19,000 pounds and in some configurations with the high energy upper stages this could go to about 25,000 pounds, when we go to our very large cluster we reach a load-carrying capability of 150,000 pounds.

This is the first vehicle that enables orbiting laboratories with men aboard to remain in space.

PAYLOAD GROWTH FOR 22,000-MILE ORBIT

Now, another orbit of considerable interest particularly to meteorology and communications is this one labeled 22,000-mile orbit, because there is an orbit where the satellite will remain exactly overhead. It is a 24-hour orbit and since this is the same time that it takes the earth to rotate in a day, the satellite will remain overhead. If we put three of these around the world, here and here, at 120-degree distances, we will be able to send signals from one to the other and provide worldwide communications. We are very interested in developing booster systems that will provide us load-carrying capability to put loads into this orbit that we are interested in—loads that are heavy enough so that you can actually put a power supply aboard that will give us enough signal strength to do this communications job, broad band television, for example. To do that we need to get at least 3,300 pounds aboard. We desire to get 5,000 pounds of load.

PAYLOAD GROWTH FOR LUNAR LANDING

Now, another space project that has been of considerable interest has been the problem of lunar landings. How soon and with what type of vehicle can we actually make a soft landing on the moon?

There have been many idle remarks made about soft landings on the moon. But in fact until we reach a capability of 730 pounds for a soft landing it is not too useful to even try a landing. The amount of exploration that you could accomplish after you were there may or may not pay for the trip. We are anxious to get boosters with a capability that will enable us to put objects on the moon that will enable us to learn something after we are there.

Now, I think this is an interesting point. With this large cluster we can put 20,000 pounds in a soft landing on the moon. But unfortunately, if we are talking about landing a man on the moon, we find that if we ask this package that we have to land softly on the moon and to return from the moon back to the earth, this figure drops to something like 2,000 pounds. Since 2,000 pounds is about the minimum weight we can conceive of to take one man and to house him properly, and to condition him for the trip, we must have the large clustered booster before we can actually think of taking a man to the moon.

COMPARATIVE MARS MISSIONS

I mentioned earlier that even though we develop these large chemical systems, there are still some missions for which advanced systems are required. This chart shows a nuclear rocket system.

If I take this booster that I just described with 6 million pounds of thrust, and mount on top of it as an upper stage a nuclear rocket system, and I fire it out into space, I find that I can get a great deal larger load-carrying capacity than if I were to take the same large chemical booster and put another chemical rocket on top of it.

This is achieved because the nuclear rocket basically gives a very much higher thrust per pound of fuel burned. In other words, it is more efficient. We can compare on this chart, for example, how much load we can take to Mars if I start with a big booster and put this nuclear rocket on top.

With the chemical system I can take 7,500 pounds to Mars and return with 750 pounds. However, if I use a nuclear system in this configuration, I can take a payload of 55,000 pounds which is some 7 times as much, and I can return with over 30 times as much.

This relative load carrying capacity arouses the interest in the nuclear rocket.

Currently it is in a research and development phase. The AEC is doing the reactor part of the job. We are attempting to take care of the pumps and tanks and we are working closely with the AEC and supporting them in the whole effort.

It will be a number of years, I think, before a vehicle with a nuclear engine can be actually developed to the point of usefulness.

However, because of the large gains, apparent from this chart the nuclear engine is a program we must push ahead with just as rapidly as we can.

This entire booster program, as I have outlined is, as Dr. Glennan mentioned, quite an expensive venture. But it is also quite clear

that unless we move ahead with it now, vigorously and with a sense of urgency, that in the years ahead we may find our space program will be wholly inadequate.

Senator STENNIS. That is a very good statement.

Can you be back tomorrow, Dr. Silverstein?

Dr. SILVERSTEIN. Yes, sir.

Senator STENNIS. Mr. Cortright, too.

Dr. DRYDEN. We will all be back tomorrow.

Senator STENNIS. Since it is 20 minutes to 5, it appears to the Chair we cannot conclude our hearing today and should suspend at this point. Is that agreeable to the committee?

Gentlemen, we thank you very much for your fine attention here and your attendance, and for your fine presentation.

Without objection, the committee will now take a recess until 10:30 tomorrow morning.

(Whereupon, at 4:40 p.m., the committee recessed until 10:30 a.m., Friday, February 20, 1959.)

NASA SUPPLEMENTAL AUTHORIZATION FOR FISCAL YEAR 1959

FRIDAY, FEBRUARY 20, 1959

U.S. SENATE,
SUBCOMMITTEE OF THE COMMITTEE ON
AERONAUTICAL AND SPACE SCIENCES,
Washington, D.C.

The subcommittee met, pursuant to recess, at 10:30 a.m., in room 212, Old Senate Office Building, Senator John Stennis presiding.

Present: Senators Stennis, Dodd, Cannon, Wiley, Smith, and Martin.

Also present: Max Lehrer, assistant staff director; Everard H. Smith, Jr., counsel; Dr. Glen P. Wilson, chief clerk; and Dr. Earl W. Lindveit, assistant chief clerk.

Senator STENNIS. The committee will come to order.

I wish to note for the record that Senator Young was required to be out of the city today. He is sorry to have to miss today's session of the subcommittee.

I have a very brief statement. We appreciate the quiet and order that prevailed yesterday—for the benefit of the witnesses, the press, visitors, and incidentally, for the benefit of the committee, too.

I think when members of the press are here, they are entitled to special consideration in that regard, because they are performing a very high public function in reporting hearings.

We will continue our testimony today generally along the same lines as yesterday.

I think it would be well if we could go over into the 10-minute rule today, if that is satisfactory to the committee. Yesterday we heard a presentation by Dr. Glennan, Administrator of the National Aeronautics and Space Administration. Dr. Glennan, while not present this morning, is holding himself available and will return for additional questioning whenever we call him.

I understand, members of the committee, that Dr. Glennan is compelled to leave town at 1 o'clock today. He has been on a standby basis for today, however I think it will take us beyond 1 o'clock to finish this testimony. Therefore, if it is agreeable to the Committee, we could review all of the testimony after it is concluded, and then let Dr. Glennan come back at some time next week—convenient to all of us—for any summing up he wishes to do, or for any further questions. Otherwise, we frankly will have to send for him now, or sometime soon, in order to hear him at all today.

Is there objection, then, to passing that matter over subject to the call of the Chair later for Dr. Glennan?

Senator Dodd, we were just saying that Dr. Glennan was here yesterday, and that we did not ask him to come back today because he has to leave town at 1 o'clock.

All right. Without objection, then, we will proceed on that arrangement.

We also heard the introductory remarks of Dr. Hugh Dryden, who is Deputy Administrator of NASA, and heard Dr. Silverstein's presentation on advanced technology.

I feel that yesterday's testimony was characterized by clarity of presentation in a highly technical subject matter area, and by refreshing candor.

Doctors Dryden and Silverstein have returned today, along with other key officials of NASA, to conclude that Administration's presentation in justification of supplemental appropriations for fiscal year 1959.

Today we have Mr. Edgar M. Cortright, Chief of the Advanced Technology Program; Dr. Homer E. Newell, Jr., Assistant Director for Space Sciences; Mr. De Marquis D. Wyatt, Technical Assistant to the Director of Space Flight Development; and Mr. Ira H. Abbott, Assistant Director of Research, Aeronautics and Flight Mechanics.

(The biographical sketches of Mr. Cortright, Dr. Newell, Mr. Wyatt, and Mr. Abbott follow:)

EDGAR M. CORTRIGHT, CHIEF, ADVANCED TECHNOLOGY PROGRAM

Edgar M. (Maurice) Cortright was appointed chief of the advanced technology program in the Office of the Assistant Director for Advanced Technology when the National Aeronautics and Space Administration was established on October 1, 1958. Before joining the NASA headquarters staff, he was chief of the plasma physics branch at the Lewis Laboratory in Cleveland, Ohio.

Cortright joined the National Advisory Committee for Aeronautics, the predecessor of the NASA, as an aeronautical research scientist on the staff of the Lewis Laboratory in 1948. From 1949 to 1954, he was head of the small supersonic tunnels section; from 1954 to 1958, he was chief of the 8- by 6-foot supersonic wind tunnel branch at Lewis. In January 1958, he was appointed chief of the plasma physics branch.

A native of Hastings, Pa., Cortright served as an officer in the U.S. Navy from 1943 to 1946. He earned a bachelor of aeronautical engineering degree in 1947 and a master of science in aeronautical engineering degree in 1949, both from Rensselaer Polytechnic Institute.

During his research career, Cortright has specialized in high-speed aerodynamics, particularly problems related to air induction system design, jet nozzle design, and interactions of a jet with external airflow. He is the author of several technical reports and articles. He is a member of the Institute of the Aeronautical Sciences.

Cortright is married to the former Beverly Hotaling. Mr. and Mrs. Cortright and their two children, Susan J., 10, and David E., 8, live at 6909 Granby Street, Bethesda, Md.

HOMER E. NEWELL, JR., ASSISTANT DIRECTOR FOR SPACE SCIENCES

Homer E. Newell, Jr., joined the staff of the National Aeronautics and Space Administration as Assistant Director for Space Sciences on October 20, 1958. Previously, at the U.S. Naval Research Laboratory he was Acting Superintendent of the Atmosphere and Astrophysics Division and also Science Program Coordinator for Project Vanguard, the United States scientific earth satellite program.

A native of Holyoke, Mass., Dr. Newell earned both his bachelor and master of arts degrees from Harvard University, and his doctor of philosophy in mathematics degree from the University of Wisconsin in 1940.

From 1940 to 1944 he was an instructor and later assistant professor at the University of Maryland, and a ground instructor in navigation with the Civil Aeronautics Administration from 1942 to 1943.

Dr. Newell joined the Naval Research Laboratory in 1944, and became Head of the Rocket Sonde Branch in 1947. In this position, he was in charge of the

upper atmosphere research program of NRL. In 1955 he was named Acting Superintendent of the Atmosphere and Astrophysics Division.

His scientific committee memberships have included the Special Subcommittee on the Upper Atmosphere of the National Advisory Committee for Aeronautics (1947–51). and the Rocket and Satellite Research Panel (formerly Upper Atmosphere Rocket Research Panel) since 1947. He is currently Chairman of the Rocket and Satellite Research Panel.

Dr. Newell is the author of several technical books and numerous articles. He is a member of Phi Beta Kappa, Research Society of America, the American Geophysical Union, the American Rocket Society, and he is a Fellow of the American Association for the Advancement of Science.

Dr. Newell, his wife, and their four children live at 4401 Westbrook Lane, Kensington, Md.

D. D. Wyatt, Technical Assistant to Director of Space Flight Development

D. (DeMarquis) D. (Dale) Wyatt was appointed Technical Assistant to the Director of Space Flight Development when the National Aeronautics and Space Administration was established on October 1, 1958. Previously he was a member of the headquarters staff of the National Advisory Committee for Aeronautics, the predecessor of the NASA.

Wyatt is a native of St. Joseph, Mo., where he attended local grammar and high schools. He earned a bachelor of science degree in mechanical engineering from Missouri School of Mines and Metallurgy in 1941.

From 1941 to 1942, he was a test engineer with General Electric Co.; and from 1942 to 1944, he was an instructor in mechanical engineering at Missouri School of Mines and Metallurgy.

Wyatt joined the NACA as a research engineer at the Lewis Flight Propulsion Laboratory, Cleveland, Ohio, in 1944. At Lewis he specialized in supersonic propulsion research, and ultimately was made Associate Chief of the Propulsion Aerodynamics Division. He was transferred to the NACA headquarters, Washington, D.C., in September 1958.

A member of the Institute of the Aeronautical Sciences, Wyatt is the author of numerous technical reports and scientific articles.

He is married to the former Louise Dunlap. Mr. and Mrs. Wyatt and their two children, Katherine, 11, and Keith, 8, live at 8407 Westmont Terrace, Bethesda, Md.

Ira Abbott, Assistant Director of Research (Aerodynamics and Flight Mechanics)

Ira H. (Herbert) Abbott was appointed Assistant Director of Research (Aerodynamics and Flight Mechanics) when the National Aeronautics and Space Administration was established on October 1, 1958. He had served with the National Advisory Committee for Aeronautics since 1929.

Abbott supervises basic research programs of NASA in fluid mechanics, aircraft, missile, and spacecraft aerodynamics, and control guidance and navigation.

Born July 18, 1906, at Wolfeboro, N.H., Abbott was graduated from Newburyport (Mass.) High School. He received a bachelor of science degree from Massachusetts Institute of Technology in 1929.

Following his graduation, he began his career with NACA as a junior aeronautical engineer at Langley Aeronautical Laboratory, Virginia. He was promoted to Senior Aeronautical Engineer in 1941, and named Langley's Assistant Chief of the Full-Scale Research Division in 1944. The following year he became Assistant Chief of the Research Department.

Abbott was transferred to NACA headquarters, in Washington, in 1948 as Aeronautical Consultant and was named Assistant Director of Research (Aerodynamics) in 1950. He has written numerous technical publications.

He is a member of the Civilian-Military Liaison Committee, authorized by the National Aeronautics and Space Act of 1958, and a Fellow of the Institute of the Aeronautical Sciences. From 1957 to 1958 Abbott was Chairman of the Wind Tunnel Panel of NATO's Advisory Group on Aeronautical Research and Development.

Mr. and Mrs. Abbott (the former Martha Leola Streeter) have three children and live at 3704 Bradley Lane, Chevy Chase, Md.

Senator Stennis. Those witnesses who are going to testify today who were not sworn yesterday will please stand.

Do you, and each of you, solemnly swear that your testimony before this committee will be the truth, the whole truth, and nothing but the truth, so help you God?

Mr. CORTRIGHT. I do.

Dr. NEWELL. I do.

Mr. WYATT. I do.

Mr. ABBOTT. I do.

Senator STENNIS. All right. If there is no objection we will proceed in the usual fashion, and we will invoke the 10-minute rule, which means that these gentlemen will not be interrupted except in an emergency. At the end of their statements we will proceed to questioning by the Senators and the staff members for 10 minutes, and the Chair will call the time and we will pass to the next Senator.

All right, Dr. Dryden.

TESTIMONY OF DR. ABE SILVERSTEIN—Resumed

Dr. DRYDEN. Do you want to question Dr. Silverstein on his presentation yesterday?

Senator STENNIS. We concluded rather rapidly there, and we have some questions now. I don't know just who will answer all of them, but we do have one matter that we want to direct to Dr. Silverstein, if it is agreeable with the committee.

This is a committee question, I think, as prepared by the staff.

Yesterday Dr. Glennan said—this is directed to Dr. Silverstein—that it would cost $200 million to develop the single-chamber million-pound-thrust booster, and it would cost $20 million each time one was sent into space with a payload.

COST ESTIMATES OF BOOSTER VEHICLES

Now, Doctor, can you give us either now or for the record estimates of the cost of the other booster vehicles you discussed yesterday, or at least some of them?

Dr. SILVERSTEIN. May I put that in the record, sir?

Senator STENNIS. All right.

(The information referred to follows:)

Development and unit costs of space program vehicles

	Cost of development	Cost per unit after development [1]
Existing vehicles:		
Thor-Delta	[2]	$2,500,000
Thor-Able	[2]	3,700,000
Atlas-Able	[2]	6,500,000
Juno II	[2]	2,250,000
Jupiter	[2]	2,250,000
Atlas	[2]	3,600,000
Vehicles under development:		
Scout	$6,300,000	500,000
Vega	24,300,000	5,000,000
Centaur	36,200,000	7,500,000
Juno V	250,000,000	15,000,000
Nova engine	200,000,000	[3] 2,000,000

[1] Without payloads.
[2] Developed under missile program.
[3] Engine only.

Senator STENNIS. Does any other member of the committee have any special questions for Dr. Silverstein at this time?

Senator Cannon.

Senator CANNON. Doctor, you were just queried concerning the million pound single thrust engine. When you were referring in your charts yesterday to the force that would be required to put it out for a 300-mile orbit—or the 20,000 pound load—you referred to the million pound or the 6 million pound cluster. You were not referring to the single engine million pound thrust engine that is in experimentation now?

Dr. SILVERSTEIN. Perhaps by the chart I could show—have you you got the chart showing that?

CLUSTER ROCKETS

The cluster rocket is made up of a number of the 6 million pound thrust—is made up of a number of the million to a million and a half pound rockets clustered together, and I think that shows on the right hand.

Senator CANNON. I understand that, Doctor. Direct your attention to the million pound cluster, perhaps that would explain it a little better.

Dr. SILVERSTEIN. With the million pound cluster here we have existing engines being used currently in our ICBM and IRBM missiles that are simply brought together in a cluster, you can see the various engines here, and require no new engine development.

Senator CANNON. So that the diagrams you used, and the testimony that you gave, related to the engines already in existence as distinguished from the engine about which the chairman asked you a moment ago?

Dr. SILVERSTEIN. Yes, sir.

Senator CANNON. Thank you.

Senator STENNIS. All right; thank you, sir.

Senator Wiley, we are continuing our testimony where we left off yesterday with Dr. Dryden and Dr. Silverstein, and we have other witnesses.

Dr. Glennan is not here now, but he will be coming back before we conclude this testimony.

We have agreed that today we would have the 10-minute rule as to each Senator when it comes time for questioning, and we will let these gentlemen make their statements without interruption except in an emergency.

Now, are there any other questions before Dr. Dryden, or whoever he calls on, proceeds?

(No response.)

Senator STENNIS. All right; let us proceed, Doctor.

TESTIMONY OF DR. HUGH L. DRYDEN, DEPUTY ADMINISTRATOR, NASA

Dr. DRYDEN. Yes. I will make the next presentation on Project Mercury.

STEPS IN ACHIEVING MANNED SPACE TRAVEL

The general subject of the man in space, the Project Mercury, is, of course, but the first step in the long road that leads to true space travel of man.

The first chart shows what might be considered as milestones down this road. (Chart references apply to chart series 2 in appendix.)

The first one is the X–15 research airplane which will begin its flights very shortly, and which will within a year or so enable man to briefly escape from the atmosphere, as a fish escapes from the water, to reenter the atmosphere, and thus study some of the problems that we encounter in space.

For example: When there is no air, we cannot control the airplane by ordinary control surfaces, we must put on little jets or rockets, space-type control, so the X–15 is provided with that and we can study that form of control.

It also must safely re-enter the atmosphere and is subjected to intense heating, so that the surfaces of the X–15 at the maximum heating of reentry may actually glow red. But the structure is designed to take that. We can study the reentry problem.

We also enable the man to be subjected to weightlessness for about 4 or 5 minutes so he is acquainted with this new phenomenon.

The second project is the Project Mercury, which is the simplest vehicle to put a man in orbital flight, and most of what I have to say will deal with the project which is the highest priority project of NASA, one of which we are putting a great deal of urgency and effort into. Off beyond this come other types of orbital vehicles.

The next in which there is more control over the landing position, I will go into in just a moment.

Beyond that is the matter of the space station of several men for several days; a permanent manned orbiting space laboratory; manned flight to the vicinity of the Moon; manned landing on Moon and return, and finally interplanetary flight.

As I say, I will talk about Project Mercury which is actively proceeding, and a little bit about the next steps which are in research and development.

There is some very long-term thinking, and so on, going into the latter phases of this, and as you heard from Dr. Silverstein, the boosters which are required to do some of these later missions are in the program and actively being developed.

OBJECTIVES OF PROJECT MERCURY

Now, Project Mercury has the philosophy along this line:

The objectives, as I have mentioned, are to put a man in a satellite which goes around the earth a few times, and that, by the way, is rather easily done, but we wish, of course, to recover him safely to get this experience, the technology which will permit this and to study something of man's capabilities in this kind of an environment.

Rather simply, in this project, can he talk and communicate; can he do certain types of control functions; can he navigate; will he know where he is, and so on.

The basic principles are to take the simplest and most reliable approach with a minimum of new developments, not to wait for some new research program to be finished which would lead to a new material or a new principle, but to take the present state of the art, to adopt a program which builds up to this accomplishment and gives us confidence, such confidence that we will be willing to commit a man to this mission. I think you will see that as we go along.

Now, everyone who has studied this problem chooses as the simplest and quickest method of doing this the so-called drag vehicle, which in layman's language is to substitute a capsule for the nose cone of a ballistic missile, and to use the ballistic missile booster to put the capsule into orbit.

To get down again, the capsule is equipped with retro-rockets, rockets which will slow it up. When the drag vehicle is slowed up it will approach the earth and return to earth, into the ground.

The final stages of the recovery are to be made by parachute, with a descent planned on water, and throughout, the safety of the man has been a paramount consideration, and the requirement in the project is to provide an escape system so that even if the booster burned on the launching pad, it would be possible for the man to get out safely from such a vacuum, or if for some reason the performance of the booster was under its nominal performance and the vehicle did not go into orbit, it would be possible for the man to get out.

BALLISTIC CAPSULE

This is the general philosophy, this is a cross-section of the capsule, what it looks like.

Here is a small model of it. I think many of you have seen pictures of this already. I won't dwell on it too much.

The man would be placed in a pressure chamber to protect him against the vacuum. He would be provided with life support equipment.

I might say that in this mission, by choosing to deal with a period of a few times around, we will say a period of the order of a day, you don't have to provide a lot of food, you can use existing oxygen supply equipment to deal with the carbon dioxide, the heating and the refrigeration, you simplify that aspect of the problem which you must deal with in the longer term. But in this particular mission you don't have to worry about that complication. You use the readily available life-support equipment.

The man is supported in a reclining condition, with his feet and thighs supported in this way, in a couch which is molded to fit his form, actually encloses him in this support. This is for the purpose of protecting him against the acceleration of the launching operation, and the deceleration when he re-enters the atmosphere, but more importantly, the somewhat larger accelerations that he would get in a failure of the mission if he had to escape.

Now, this part of the problem has progressed so far that several men, several volunteers, supported in this way on a couch, have been exposed to high acceleration in the centrifuge operated by the Navy

at Johnsville, Pa., have safely withstood accelerations approaching 20 times gravity. In other words, the apparent weight of the man would be something of the order of 3,000 pounds. He would feel like he weighed 3,000 pounds, and men have gone through the experience successfully. So that we have every confidence at this stage that this kind of a system will protect the man against accelerations.

We show him here in a space suit. The idea is that there might be certain emergencies in which we would want to open this shell to the vacuum momentarily.

For example: Suppose he had a fire. The easiest way to make a fire go out is to open the case up and let the air go out and the fire go out and then renew the atmosphere with oxygen.

The parachute is shown here, and the heat shield in which we are actually going to try both heat resistant types made of beryllium.

Here are the retrorockets for slowing them up. You will see in just a moment that the man has to, or we from the ground have to control the attitude, so that although it is launched in the position that you see it, it must be turned around to re-enter so that the acceleration is the same way and the heat shield is in front. You see, the heat shield would protect him from a fire on the launching pad during the period needed to get away. It also will protect him from the re-entry heating.

On the front is this escape system, which is a rocket mounted on a pylon, having a sufficient lift, as I have said, so that if there is an accident in the early stages of flight, this rocket is fired separating the capsule from the rest of the missile and sending it on a trajectory such that the parachute can be used for recovery. This is discarded in the later phases of flight, I believe—well, this breaks down the shell into its pieces.

I don't think we need to stop on this very long, labeling various parts of it showing a small parachute to slow up and stabilize the capsule in the higher atmosphere, the larger parachute, main parachute. There is also a second emergency parachute if for any reason this one does not work.

FLIGHT TRAJECTORY

The next one shows the sort of concept of the mission, a launching with an Atlas missile from Cape Canaveral. You can see this little pylon on the top at this stage. As you know, the Atlas is a so-called one and a half stage booster so that at a certain height the two outer engines drop off.

This safety system is discarded after you get out of the atmosphere, because when you are out of the atmosphere all you need to do is separate the capsule from the rest of the booster to operate the recovery system.

Injection into orbit, the separation of the capsule, as I mentioned, rotating it through 180 degrees so that the heat shield is in front when he wants to come down, fire retrorockets somewhere between Hawaii and the west coast if he is going to land in the range, in the Atlantic missile range.

When the retrorockets have been used up they are dropped off, the entrance into the atmosphere, the deployment of the parachute and landing on the water. He may go around once or several times.

Either for practical reasons with the particular pad available, the first two or three times you could recover him on the Atlantic missile

range, then you may have to wait for a full day before he comes back favorably in the same position.

MILESTONES

These are the things which have happened on the project so far. The agency was organized October 1, a task group on this project was formed on October 5. Specifications of capsules were mailed on October 23. There was a bidders' conference on November 7, proposals received December 11, contractors named January 9. Development tests have been under way.

Let me come back for 1 moment to this—I mentioned the progressive build-up of testing. Before attempting this mission with a capsule, we intend to do quite a number of things to check it out and qualify it, and perhaps some of these phases will also be used in the pilot training.

The launching system that you see here can be tested not with one of the capsules being produced by the contractor, but by mock-up of it, by just setting it on the beach at our Wallops Island launching station, firing the rocket and seeing whether that will be instrumenting the capsule, seeing whether we can actually recover the rocket from a launching pad.

Senator STENNIS. Doctor, will you let me call the members' attention to the fact that they have before them a book containing a very fine representation of these charts.

Dr. DRYDEN. Yes.

Senator STENNIS. If you open that you can turn from one chart to the other as the Doctor's explanation proceeds. Each of these charts are represented in the book, and it is very easy to turn from one to the other.

Excuse that interruption, Doctor. Proceed.

Dr. DRYDEN. Yes.

The next step in qualifying the capsule would be to use a cluster of four existing Sergeant solid propellant rockets to launch the capsule at a speed of five or six thousand feet per second, on a ballistic trajectory, in other words, toss it over a short range at much less than orbital speed.

Then, Redstone boosters will be used, and the Army Ballistic Missile Agency is involved in this aspect of Project Mercury, to attain higher speeds.

Then we progress finally to Atlas boosters, first starting with, let's say, the range similar to that of the intercontinental ballistic missile and finally putting the capsule into orbit.

Now, in general, in each of these phases we start with instrumenting the capsule with animal tests, and finally in some stages of it, man.

I think you can see that through all of this building up we are getting experience in knowing where this thing is all the time, getting it back. It should be obvious, I think, that if we cannot find an instrumented capsule and recover it safely, we are not yet prepared to put a man in it and try to recover it.

This buildup of testing not only tests out the capsule, not only is helpful in the certain points in training of the man, but it also exercises our whole system for tracking, communications, and recovery.

As I say, we certainly will not be willing to put a man into this mission until we have demonstrated that we can fire this thing and get him back.

MERCURY ASTRONAUTS

Now, as many of you know, the selection of the men who will be involved in this program has already started. We will wind up with a small group who will live with this project from now on, and will ride the centrifuge in Johnsville and go through other types of training, following a very tight and rigorous selection.

In general, we are making our selection from people who have engineering background, graduates of universities who have also graduated from one of our test pilot training schools in the Service, who have had considerable flight experience, and I mean training schools for test pilots, not just pilot training schools.

They must be under 40 years of age, less than 5 feet 11 inches in height. They go through very extensive physical and psychological tests.

Now, these people will live with this project from now on, and will have their input into the project.

That is Project Mercury.

POSSIBLE CONFIGURATIONS

May I just put on a final chart to show you this is the simplest vehicle. The disadvantage, perhaps, is this, that it will be very difficult to control the landing point within a distance of perhaps the order of a hundred miles each way. This is not something that we can bring down on a particular spot on the earth's surface. If you want to control it you have to go in the direction toward wings.

Now, one way of getting the effect of wings is to use an unsymetrical body with some control tabs. Another is a winged vehicle, and I won't go into this. This becomes a somewhat more difficult problem for many reasons. It will take longer to do this than to do that. That is why we start with Project Mercury.

Well, this is the few years ahead down this road which eventually, as we develop the technology and gain the experience, will lead to the travel of man in space. It also will lead, we are quite sure, to various types of operations in space of very great value.

We think, for example, in terms of communications satellites that we were taking about, or manned laboratories in space. We must develop the methods of getting up there and back again, so that we can take man there and bring him back again, if we are to do useful jobs. Otherwise, we will find ourselves as we get to more and more complex communications satellites with very great expense, of putting them up repeatedly as the power supply fails, for example.

This ends this particular presentation, and I would be glad to answer any questions that I can.

Senator STENNIS. I have just a brief question.

The last chart you have up there, Doctor, the winged part now——

Dr. DRYDEN. Yes.

Senator STENNIS. Isn't that comparable or related to one of the Air Force projects that they are working on? I don't know whether this is classified or not, the question I am asking.

Dr. DRYDEN. No.

DYNA SOAR PROJECT

Senator STENNIS. The Dyna Soar.

Dr. DRYDEN. The Dyna Soar has some resemblance. Dyna Soar at the present time is a—Dyna Soar I is a vehicle which will ride within the atmosphere at speeds from the speed of the X–15, which is several times the speed of sound, up to satellite speeds which are in, get up to the order of 20 times the speed of sound or more. There is a range there which the Dyna Soar is intended to explore.

Now, it is conceivable that the Dyna Soar can be later developed into this type of vehicle. Our general feeling is something like this: If you are going to be in the atmosphere, if you are going to land in the normal manner of an airplane, you have to have a fair amount of wing surface. The higher you go out into space the less wing you would like to have on it, because this requires very much larger boosters. It is like all of these engineering problems, it is a compromise.

So this does represent the approach from the airplane side of the picture. This represents the approach from the missile side of the picture. This is kind of halfway between.

Senator STENNIS. I see. I believe that is all.

Senator Smith.

Senator SMITH. I haven't any questions at the moment, Mr. Chairman.

Senator STENNIS. Senator Dodd.

Senator DODD. No, thank you.

Senator STENNIS. Senator Martin.

Senator MARTIN. Have you made some approach to the matter of spinning the instrument without spinning the man inside?

Dr. DRYDEN. No, sir. This will be controlled in attitude by these roll jets, pitch jets, and yaw jets. In other words, it will have an automatic pilot like an airplane and a gyrsocopic reference, stable platform reference to maintain it in the desired attitude. It does not roll; it is a stable object and doesn't oscillate.

Senator MARTIN. You can have a stable object that will not tumble?

Dr. DRYDEN. Yes. This is the background of this design, yes.

Senator MARTIN. That is all.

Senator STENNIS. Senator Cannon.

REENTRY CONTROL

Senator CANNON. Doctor, now in the ballistic missile configuration there, is there any control after the missile re-enters the atmosphere?

Dr. DRYDEN. No, sir.

Senator CANNON. You have no direction of control?

Dr. DRYDEN. No, sir. We have to track this thing with sufficient accuracy so that we can predict fairly closely where he is going to land, and communicate with the recovery groups.

PROJECT TIMETABLE

Senator CANNON. In your Project Mercury milestones, you set forth the dates of various steps. However, you did not give any estimated date of completion.

If that information is not classified, I wonder if you would care to comment on it.

Dr. DRYDEN. We, of course, do have a target timetable of the steps in the program that I described. I also said that we will not put a man in it until we have recovered this thing quite a few times, and I can't tell you just exactly what date that will be. In the course of a very few years we will know.

Senator CANNON. You say that the contractor has been named—the capsule contractor?

Dr. DRYDEN. The capsule will be delivered in about 14 months.

Senator CANNON. I see; 14 months from the date of the contract, which was January 9.

Dr. DRYDEN. Yes.

Senator CANNON. And of course the escape system tests—you don't know except as those develop as to when they may likely be concluded.

Dr. DRYDEN. Yes, if we could guarantee to you that there could be nothing we haven't foreseen and provided for, then we could give you the date at which we might put one of these in orbit as an instrumented capsule. But the experience in these things usually is that you run up against problems that you didn't foresee that you have to lick, and this is why the time scale is difficult.

X–15 PROGRAM

Senator CANNON. Now, to get back to the X–15. Is NASA conducting the tests on these short-range flights of the X–15?

Dr. DRYDEN. We have the technical direction of the flight program. It is a cooperative project between the Air Force, the Navy, and ourselves. The Navy, for example, has some money in it, and it is a Navy developed engine.

The Air Force was the agent for procuring the money, supervising for the building of the airplane. We have been represented at all stages in this, but the money was in the Air Force budget. The money in our budget was for instrumenting the airplane, and the operations will be done actually under the group at Edwards Air Force Base, the controlling group, as our plan with Air Force and naval people in the project, pilots, includes NASA pilots, Air Force pilots, Navy pilots. You have read the names of three of them in the papers. Crossfield, from the contractor, Joe Walker of our laboratory, and I am afraid I don't know the names of the others. Do you remember them—Captain White from the Air Force. There is a naval officer also, Senator.

Senator CANNON. Is there any experimentation being done toward putting the X–15 itself, with some minor configurations, into orbit?

Dr. DRYDEN. That is not practical.

Senator CANNON. That is not practical.

Dr. DRYDEN. There would be a very extensive redesign to amount to a new airplane, in our opinion.

Senator CANNON. I wondered if that might fit into your winged program.

Dr. DRYDEN. A follow-on development might very well. But it would, in my opinion, be a somewhat different configuration of materials, and so on, so much so as to be practically a new airplane.

VALUE OF PROGRAM

Senator CANNON. Doctor, yesterday you heard me ask Dr. Glennan about the value of this program in view of the fact that the American public is going to be very vitally concerned with having approximately a billion dollars a year spent on a space program.

Dr. DRYDEN. Yes, Senator.

Senator CANNON. In view of budgetary problems at the present, I would like to have you state your views as to the value of this program, compared to its cost, in our overall budget picture today.

Dr. DRYDEN. Yes, sir.

I think I mentioned that the situation is a little bit like determining the value of the airplane at the time of the Wright brothers. We have the utmost confidence, based on the past, if nothing more, that man is going to be in space, find useful things to do in space; that we must begin to study the problems associated with that.

This project, in my mind, will advance the general technology of space at a faster rate than almost anything else that I can think of.

If you do not have such an integrating project, what you get engaged in is a lot of research in various directions but not concentrated on accomplishing a mission, and we found in the X–15, for example, that this enabled a much greater integration and advance in the technology of high-speed flight than you could get by all sorts of general research.

Now, basic research is necessary, but this must be followed by research directed toward a mission to work out the applied research and the development problems, and this, I think, is one of the great returns which will come.

A secondary result of all of this work already reflected rather widely throughout our industrial structure are the developments in materials, devices, fabricating methods which come because this is at the forefront of our technology. The most difficult jobs that you could possibly think of.

Take the rapid development of transisterized and miniaturized equipment. To do these early satellites you have to make those developments.

Now as a byproduct, this has given you hearing aids that are in your spectacles. I do not mean to imply the space program has done this. The electronics program which was certainly stimulated by our missile program in this direction, has brought you such devices, and very small radios and all the rest of it.

The things developed in our ballistic missile program and space program have a tremendous influence in directions that you would not think of at the start.

Now, from a purely practical point of view, as I mentioned in the beginning, I do not think you could go to a banker and sell him on security and prove to him that you know just how he is going to get his money back. But again I say, if you look back at the airplane you could not have proved, in fact I mentioned that as a result of the lack of faith in our own country, the airplane was taken abroad and developed in other countries, and we entered the First World War without an airplane of our own and we had to buy them from other countries.

Now, you couldn't prove at that time the industry that you see today. No one looking at the wire and wood over here in the Smith-

sonian could contemplate, it is amazing now, that in 50 years you have gone from that to the big bombers, to the jet transports that we see today.

I think there is every confidence that space is going the same way. I don't know how fast; how fast depends on how much money you put into it.

I think Dr. Glennan made this point: that if it were not for the competitive aspect of the situation, perhaps it wouldn't go this fast, it wouldn't put this much money into it, but you would go in this direction, and if we don't someone else is.

Senator CANNON. Of course Dr. Glennan, in answer to my question, stated that he felt man's natural curiosity would carry this project forward—but I am not unmindful of the adage that "curiosity killed the cat."

Dr. DRYDEN. I would not try to sell a billion-dollar program to gratify somebody's curiosity, even that of a scientist.

Senator CANNON. Your feeling, then, is that the expenditure of a billion dollars a year on this project, keeping in mind our current budgetary problems, is money well spent?

Dr. DRYDEN. I do, in view of all the factors, the world situation, as we find it. What did it cost us for the Russians to put up the first satellite? I don't know how you measure that in dollars.

Senator STENNIS. Excuse me, Senator, your time is up.

Senator Wiley.

PROGRESS OF PROGRAM

Senator WILEY. I have been intrigued, Doctor, with your presentation this morning—and with the line of questioning that the Senator has indulged in.

I am at a loss, not being a scientist, concerning how much of this remains in the field of exploration and how much has been definitely ascertained.

Dr. DRYDEN. I was trying to make the point that this project is based on the idea of using, as far as possible, the research information and development information that you have at hand, so as to keep the number of unknowns as few as possible. So that I would say that the elements in this have been tested pretty thoroughly.

We have to go from the elements, now, to a practical device and to practical operation of that device.

Senator WILEY. Well, how much of it have you arrived at that is definite and certain, now? You have gotten up three or four hundred miles. Now, do you know whether man can live up there?

Dr. DRYDEN. Yes. I failed to mention that another problem that this Project Mercury postpones to the future is that of the radiation hazard of the great radiation belt which begins several hundred miles up. This is essentially an orbit in the general order of 100 to 130 miles, below the radiation belts, so that we do not have to introduce shielding into the vehicle as we most certainly will have to do when we go to higher altitudes, or start sending people to the Moon, perhaps. That is not involved in this project.

You have read of the ground experiments of people who have lived in, shut up in sealed chambers and narrow quarters for several days, many days, and of coursethis becomes a quantitative matter.

If we had the thrust to put the *Nautilus* in space, we have the problem of living for months all settled, because the crew of that submarine has lived below the ocean for months.

So I say, if we could put the *Nautilus* as an object into orbit, we wouldn't be troubled with the problem of keeping people, feeding them, and so on, for a like time.

Our problems arise from the fact that we want to do this with smaller weight than the *Nautilus* has.

RUSSIAN CAPABILITY

Senator WILEY. Do you want to tell us what your best judgment is as to how far the Kremlin has advanced with its experiments?

Dr. DRYDEN. They have the capability of doing this before we do, and I think that we have to prepare the ideas of the American people for the fact that they might do it before we do. This is related in part to the booster capacity. I remind you that our Atlas boosters are just now approaching a reliability where we can consider it for this.

I might also say that it is my belief that the ballistic missile program has to take priority over this program, if there is any real conflict on availability of the devices.

Senator WILEY. Do you think the last shot that the Kremlin got off got to the Moon?

Dr. DRYDEN. It went past the Moon. We know that it went past the Moon.

Senator WILEY. Have you got credible evidence of that?

Dr. DRYDEN. Yes.

Senator WILEY. That is all, Mr. Chairman.

Senator STENNIS. Thank you, Senator Wiley. We are especially glad you could be with us this morning. You are an ex officio member, but you are a strong member, and we appreciate your coming.

I have one or two other questions on which I will be brief.

SAFETY FACTOR

You mentioned here that if you brought this manned vehicle down within 100 miles of your estimate, that would be considered fairly good aim. You have got a safety factor problem there, I know. Do you look upon that as very grave—if you can get it down to the earth you think you can handle the safety factor on landing?

Dr. DRYDEN. We must demonstrate that fact before we put a man up.

Senator STENNIS. Of course. That is not an insurmountable matter, is it, the safety factor?

Dr. DRYDEN. We don't think so. We have, of course, invited the cooperation of the military departments, the Navy, they are in this with us on the planning of it.

Senator STENNIS. Well, do you consider that a relatively minor matter?

Dr. DRYDEN. No: I don't consider it a relatively minor matter.

Senator STENNIS. You consider it a serious matter?

Dr. DRYDEN. I think it is a major matter, and this is one of the things that we will find out in this build up, and this is one reason I didn't want to say definitely we know exactly when we are going to put a man into space.

NUMBER OF CAPSULES

Senator STENNIS. You spoke of capsules. How many capsules were you buying for these tests you make?

Dr. DRYDEN. Approximately a dozen, as I remember it.

Senator STENNIS. A dozen?

Dr. DRYDEN. Yes, I believe that is the number, but it is confused, because there are extra heat shields and extra parachutes and other sorts of things.

Senator STENNIS. Let me commend you gentlemen for what appears to be a very effective job of getting organized and proceeding right down to business. You were organized on October 1, 1958. Of course you inherited a fine organization.

Dr. DRYDEN. That is right. We had a running start.

Senator STENNIS. You inherited a fine organization, but you had this space task group formed 5 days later, on October 5. On October 23 you had your capsule specifications mailed. On November 7 you had a business conference—by December 11 proposals were received—and on January 9, 1959, a contractor was named.

Dr. DRYDEN. And to complete this, the contract has been signed, a definitive contract, not a letter of intent. The contract has been negotiated, I have forgotten the date.

Senator STENNIS. Well, Senator Smith called my attention to these facts, and I thought the record ought to show we all approved and commended you.

Are there other questions before we proceed to the next phase of Dr. Dryden's presentation?

Senator SMITH. Mr. Chairman, one other thing on what you have just been saying. I would be interested to know how much time it took before those dates to get to the point of making a contract in such a short time.

Dr. DRYDEN. The specifications were—well, let me see—I don't know whether I can answer this. We certainly, of course, had done some thinking about this, but I believe there was no attempt to write the specifications until very shortly before this time.

You will recall that I think Dr. Glennan was sworn in late in August, and obviously we could not proceed so definitely on this until we had an Administrator, so it can only be a matter of a month or 6 weeks in which any work was being done on the contract.

Now don't let me be misunderstood. The old NACA had been doing wind tunnel work on capsule shapes, studies of this problem for the past couple of years.

Senator SMITH. That is a good explanation.

Dr. DRYDEN. This was not a new agency going into business on October 1 and suddenly getting in this position.

Senator STENNIS. Senator Cannon, you indicated that you had an additional question.

COST OF PROJECT MERCURY

Senator CANNON. Doctor, in your supplemental request here you have a figure of $20,750,000 for manned space flight. Does that include the contract price of these capsules that you are talking about?

Dr. DRYDEN. No, that is in the 1959. This—really, the major part of this is commitments necessary at this time to have Atlas

boosters when we want them. In other words, it takes about a year to 18 months from the time you place your order for an Atlas before you get it.

Senator CANNON. So the capsules are actually in the fiscal year 1960?

Dr. DRYDEN. That contract, as I recall, is about $18 million.

Senator CANNON. Are those capsules expendable items?

Dr. DRYDEN. No, sir.

Senator CANNON. In other words, will you be able to reuse them?

Dr. DRYDEN. We must. Of course if we can't get them back, then we aren't—besides these capsules we, of course, have built things in this external shape and the early testing is done with that. These are capsules which are fitted, can be fitted, for complete mission.

Senator CANNON. I see. Thank you.

SIZE OF CAPSULE

Senator WILEY. What do you mean by the contract, now?

Dr. DRYDEN. Contract with McDonnell Aircraft for design, development, building of a number of these capsules containing the man, of which this is the model.

Senator WILEY. And that is going to take 18 months?

Dr. DRYDEN. Fourteen months, I believe. Our guess is a little bit longer than that, but I believe 14 months is the estimate.

Senator WILEY. How big are they?

Dr. DRYDEN. Eighty inches at the base.

Senator WILEY. What?

Dr. DRYDEN. Eighty inches at the base. The man is sitting in this thing—let me take this off. That shows the scale, the man is going in there.

Senator WILEY. This is a scale model.

Dr. DRYDEN. Yes, 80 inches. The man is a little under 6 feet, but he is sitting with his legs up.

Senator WILEY. How tall?

Dr. DRYDEN. I don't remember the number, but you see if that is 80 inches, it must be of the order of 10 feet or 12 feet.

Senator WILEY. Isn't it part of that display model over there that you are talking about, this section that is pointed?

Dr. DRYDEN. No.

Senator WILEY. This other one?

Dr. DRYDEN. No. This is the present Vanguard payload in orbit. This is a very much larger item. It weighs in the order of a ton, a little more than a ton, with all of its equipment.

Senator WILEY. Well, how are you going to get it up?

Dr. DRYDEN. With an Atlas ballistic missile booster.

Senator WILEY. That is on the bottom of this?

Dr. DRYDEN. This sits on the top end of the Atlas.

Senator WILEY. Yes.

Senator STENNIS. All right, Doctor, if you will proceed now to your next presentation. How many more phases do you want to present so that we get the overall picture, which is what we are striving to ascertain,

Dr. DRYDEN. There are seven more.

Senator STENNIS. Perhaps you want to present more than just one at a time before we ask questions.

Dr. DRYDEN. This is up to the committee.

Senator STENNIS. All right, proceed with your next one, please. For the committee, I would like to insert pages 256 through 259 of your detailed justification in the record at this point.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
FISCAL YEAR 1960 ESTIMATES

Manned space flight

Fiscal year 1959	$37, 661, 200
Fiscal year 1959 supplemental	20, 750, 000
Fiscal year 1960	70, 000, 000

1. Objectives

To provide a capability for accomplishing advanced space flight missions with vehicles where on-board human intelligence and operations are required. It will be a basic objective of the NASA to rationalize and refine the technology of manned space flight vehicles and associated systems, to achieve successful orbital flight and recovery of a manned satellite with an ICBM-booster and drag-reentry system, to evaluate the physiological and psychological effects of a space environment on man, to establish his capabilities and limitations for performing useful missions in space, and to devise and develop improved manned vehicles with increased capabilities for performing important advanced missions.

2. Justification

It is becoming increasingly evident that full exploitation of the potentialities of space flight for benefiting mankind will be dependent on the development of practical capabilities for operating manned space vehicles. While it may appear in principle that suitable instrumentation may be devised to perform increasingly complex space missions, in practice the availability in a vehicle of human intelligence and operational capabilities will prove to be the most effective method for successful accomplishment of many advanced space flight missions. In particular, he can contribute to the tasks of space exploration and utilization an observational, analytical, and decision-making ability concerning both expected and unanticipated problems, and a vast flexibility of action for operation, correction, and maintenance of scientific and technological instrumentation and equipment that characterize his present usefulness in airplanes and the scientific laboratory.

In order to provide this capability a progressive program of research and development has been undertaken. A broad range of investigations directed to the solution of basic technological problems concerning vehicular configurations and construction, human factors, life support equipment and accommodations, launching systems, stabilization and control, reentry and recovery systems and techniques, operational and scientific instrumentation, and other vehicular subsystems has been initiated.

On the basis of extensive studies it has become evident that the first manned orbiting flight vehicle should be based on the use of an ICBM-booster launching system and the ballistic type of drag reentry into the atmosphere. The relative simplicity and reliability of this approach at the present state of the art offers the best potentiality for early success and will yield a vehicle with a wide range of usefulness for investigating problems concerning both human and vehicular operation factors. This vehicle is also a logical steppingstone to larger systems of the same type with greater capacity for performing both scientific, civil, and military services. In addition, it is adaptable to the investigation of both reaction-type space-path control and aerodynamic-lifting systems that will give later manned space vehicles a greatly increased scope of operations.

3. Program phasing

During the fiscal year 1959, a wide range of studies and experimental investigations is being initiated to assess the problems that will be encountered in initial development and operation of manned space flight vehicles and to establish the design requirements for the first operational vehicle. A contract for the design and construction of the full-scale manned capsule and associated instrumentation

and equipment should be let early in 1959 and the initial capsule for preliminary investigations should become available approximately 9 months later.

Booster systems including solid-rocket clusters and liquid systems up to the ICBM size are being procured to provide for a progressive series of unmanned flights at increasing velocities up to orbital speed to refine both the vehicular systems and operational techniques to insure the safety of later manned operations.

Some of these preliminary flights will also utilize lower primates to assess a range of physiological and psychological factors that will be attendant to manned operation. Concurrently an intensive program of pilot training involving centrifuge, pressure chamber, simulator, and balloon experiments will be undertaken.

Further extensions of these programs are planned for the fiscal year 1960. During this period it is expected that the first orbital flights of the unmanned fullscale capsules will be achieved and effective techniques developed for the reentry and recovery phases of the operation. If the systems and techniques prove successful, some preliminary flights at suborbital speeds with the manned capsule may be undertaken. Additional vehicle capsules and boosters and associated equipment will be procured for the continuing manned flight experiments in the following year.

During the fiscal year 1960 it is also planned to undertake the development and construction of more refined versions of the vehicle that will offer greater capabilities for performing scientific investigations in space and for providing space path control. A range of analytical studies and model experiments will be undertaken to define the optimum approach to these problems and establish the basic design requirements. Initial development of appropriate vehicles should be undertaken.

The major items to be procured for this project are the satellite capsules. A total of 12 capsules will be delivered during the fiscal year 1960; fiscal year 1959 funds will be used for the design, engineering, and early construction phases of these satellites. Boosters for short range test and qualification flights will also be purchased during the fiscal year 1959 and funds will be committed for the ICBM boosters required for the first orbital flights. The boosters for the manned orbital flights will be purchased in the fiscal year 1960.

4. Program costs

	Fiscal year 1959	Fiscal year 1959 supplemental	Fiscal year 1960
Scientific and technical studies:			
Human factors	$600,000		
Range and recovery	100,000		$300,000
Design studies of advanced systems			1,000,000
Prototypes and operational hardware:			
Capsules	11,500,000	$4,000,000	22,000,000
Boosters	21,861,200	16,000,000	27,700,000
Operations and technical services:			
Flight test operations	1,100,000		9,500,000
Range and recovery	600,000		3,000,000
Pilot training			500,000
Supplies, equipment, repairs, and alterations:			
Large scale and wind tunnel models	400,000		3,400,000
Environmental and functional test equipment for capsules and components	500,000		1,000,000
Data acquisition and handling equipment	300,000	200,000	300,000
Simulators and personnel equipment for human factor research and personnel training	150,000	500,000	500,000
All other items	550,000	50,000	800,000
Total	37,661,200	20,750,000	70,000,000

Dr. DRYDEN. Mr. Cortright will talk about the satellite applications, meteorology and communications.

Senator STENNIS. Come around, Mr. Cortright.

Mr. Cortright, we dipped into this a little yesterday, but just ignore that and present it in your own way.

TESTIMONY OF EDGAR M. CORTRIGHT, CHIEF ADVANCED TECHNOLOGY PROGRAM, NASA

Mr. CORTRIGHT. Thank you. There are a number of practical problem areas which stand to benefit greatly by the application of space technology. These include meteorology, communications, navigation, and geodetics.

I would like to attempt to give you some feeling for what we hope to accomplish in these areas. I would like to begin with meteorology.

MEASUREMENTS WITH METEOROLOGICAL SATELLITES

Now the reason the earth satellite will be so beneficial to meteorology, we feel, is twofold: One, it enables us for the first time to get truly world-wide weather observations, and secondly, by virtue of its position above the earth's atmosphere, the satellite will make possible measurements which have never been possible before.

Now, some of these measurements are indicated in the first chart here. They include, most obviously, observations of the clouds over the earth's surface. From these observations we hope to be able to determine the extent of cloud coverage, the types of clouds, their layers, thicknesses, heights above the earth, and that sort of thing. (Chart references apply to chart series 3 in appendix.)

And then we would hope to be able to measure precipitation, associated with the clouds, and the location of thunderstorms under the blanket of clouds by the electrical disturbances resulting from lightning flashes.

Another set of measurements would be directed to the determination of temperatures of the stratosphere, tropopause, cloud tops and surface of the earth. I think it is interesting to point out here that we feel ocean currents may be traced by surface temperatures, and these are related to weather, in general.

There is also hope of being able to determine some of the constituents of the atmosphere, and their distribution, such as water vapor, ozone, and carbon dioxide.

Then there is a whole set of experiments which can be related to what is frequently referred to as the heat budget of the earth. This is essentially the local imbalance between incoming solar radiation, reflected solar radiation, and outgoing radiation from the atmosphere and the earth.

Now, all of these measurements are detected by radiation sensing devices such as television cameras, radar, photocells, and thermistor bolometers.

I think as the artist has here attempted to show in this sketch, that one of the main virtues of the satellite in observing the weather is that it will give us an integrated picture over large areas. This type of picture is very difficult to generate from the ground where we have scattered observing points and you cannot see too far from any one.

CLOUD COVER AND STORM DETECTION

There has been one practical demonstration of this utility.

This photograph was obtained from a rocket a hundred miles over White Sands, and here in this outer region of the photograph we see

a rather severe cyclonic disturbance building up over the gulf coast of Texas. Now, interestingly enough, the Weather Bureau stations in the area were not able to detect this disturbance, and yet the high altitude photograph shows it very clearly. This disturbance did develop into a severe one causing considerable damage from heavy rainfall.

VANGUARD II SATELLITE

Now, we have made our first attempt to get this type of picture from a satellite with the satellite launched just a few days ago. I got into this briefly the other day, but I will attempt to summarize it again, because this chart, I think, is helpful.

This satellite contains photocells to observe the surface of the earth. They look in diametrically opposite directions. Now, they scan along a path which is curved, and this curved path, which can assume various curvatures as a matter of fact, advances with the movement of the satellite.

I tried to think of a good analogy after yesterday's discussion. One which occurred to me was to take a piece of paper, put a small hole in it, hold it in front of someone's face and scan back and forth across the face. You would see each portion of the face, but you would not know what the face looked like because you could not remember what each spot was and integrate them into a picture.

Well, in the satellite here the photocell senses the color or the level of gray of each spot and records that information on a magnetic tape. After satellite completes a pass around the earth, these data are read out of an interrogation station and recorded on tape on the ground. They are then reconstituted into a picture at Fort Monmouth where Mr. Strauds' group is located.

As historic as this first cloud satellite may be, I think it is important to recognize that it is only step No. 1; it is sort of a downpayment on meteorological satellites, in general. The satellites are going to become far more complicated, larger, heavier, and one is not going to suffice in an ultimate system.

OPERATIONAL SATELLITE SYSTEM

To give you some idea of where we are heading in this area, I have shown in the next chart what might constitute an ultimate operational system of meteorological satellites.

Here we have made use of multiple satellites in polar orbits—I have shown about six of them here. These satellites travel around the earth, as indicated, and from a relatively low altitude, 500 to 1,000 miles, they observe the many detailed measurements which I showed on my first chart.

In addition we feel that there will be need for high altitude satellites such as these 22,000-mile orbit satellites in the plane of the equator. Since it takes 24 hours for these satellites to complete an orbit they remain overhead at the equator. Now, because they are so high and can see far north and far south of the equator, our weatherman, for example, sitting in a world weather center of the U.S. Weather Bureau could direct these satellites to observe interesting situations, dangerous situations, which might be developing any place over all but the arctic regions.

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COMMUNICATIONS SATELLITES

Now, the tremendous amounts of data which will be generated by meteorological satellites will saturate the world communications system.

In fact, one satellite, taking many television pictures, can saturate the world system; and we have got to look toward better ways of getting these data back to the Weather Bureau in a hurry. After all, weather data are very perishable, as we all know.

The only way we can see at the moment to do this or at least the best way we can see to do it is with communication satellites. These satellites would enable us to relay information from this satellite back to the weather center, and from these other satellites back to the weather center, just about as rapidly as the data are obtained.

And this does lead me to the next area I want to talk about, and that is the communications problem in general, and the communications satellite.

Now, there are a few favored nations of the world, as we all know, that have good communications systems. They can handle the voice traffic within the country, and a certain amount of television. However, there are many nations of the world which have no communications by modern standards.

In addition, as far as our transatlantic ties are concerned, we are very hard pressed. The transatlantic cable, which is available today, will handle 36 channels of telephone type conversations, and yet it requires 1,000 voice channels to transmit 1 television channel across the ocean.

The present transatlantic cable will be saturated, as a matter of fact, by 1961 or 1962 with voice traffic, so we do have to look for something much better. There is a new cable under development which would not be available for another 8 or 9 years, and this will only handle 150 voice channels, so this is not promising.

Now, the communications satellite is not the only way. There are high frequency relay systems and tropospheric scattering systems, but none of these seem to offer the promise of a communications satellite.

PASSIVE COMMUNICATIONS SATELLITE

I want to show you some of the most promising ways, in our opinion, of utilizing satellites to solve the world's communication problem.

One way we call a passive communications satellite. The passive satellite consists merely of a large inflatable sphere, and our first experiment will utilize a 100-foot diameter sphere which will be made of aluminized mylar plastic, will weigh only 65 pounds, and will be placed in an altitude of 700 to 1,000 miles.

Now, the way to use a satellite like this is to bounce a very intense radio signal off the satellite. This signal is reflected from the satellite in all directions; and reaches the earth as a very weak signal, but covering a very large area.

By providing on the earth's surface highly sensitive receiving antennas which are capable of being directed toward the satellite, we are able to receive a message here that was generated here. Now, at an altitude of 1,000 miles, if the satellite were over the middle of the Atlantic Ocean, you could bounce a signal from the North American Continent to Europe.

The ultimate system will probably use such satellites at 3,000 miles altitude, which would give them nearly a 5,000-mile coverage.

Now, I guess it is quite obvious that if this is at 3,000 miles, and it is going around the earth, it won't always be in the right position, so the way you handle this problem is to put many of them up. They do not weigh too much, are not too expensive to put up, and you might use 15 to 20 of them, so that at any one instant there is always 1 satellite in a position to use, and our communications could be continuous.

100-FOOT INFLATABLE SATELLITE

Now, this next chart shows this satellite, which has already been fabricated and is awaiting availability of a booster. I brought a few samples of the material from which the satellite is made; I think you might enjoy looking at them. Although it is only one-quarter of a mil thick it has high tensile strength.

ACTIVE REPEATER SATELLITE

Now, there is another approach to the communications satellite which offers considerable promise, and that we refer to as the active repeater. For this type of satellite we send our radio signal up from the ground to the satellite and it is rebroadcast from the satellite back to a receiving station.

One of the main virtues of this type of satellite is that we can get by, we think, with three of them in an ultimate system. These three satellites would be located over the Equator, spaced 120° apart, and they would be in a 24-hour orbit, the 22,000-mile orbit. This satellite will have to be carried through a period of research and development to achieve the characteristics which we desire, but we feel that it is very promising.

I would like to conclude with a brief description of how we can use the satellite for geodetic purposes and for navigational purposes.

The large land masses of the earth at the moment are rather loosely tied together. It is true that the land masses where civilization is developed to its fullest have been well surveyed within their own borders. For example on the North American and European continents we know distances to within 75 feet in 3,000 miles (across the United States).

But the continents themselves have been tied together by radio means, radio surveys, and these accuracies are quite a bit poorer, say, three-tenths of a mile. The islands are out of position even farther, say a mile, which is about the best we can do with celestial navigation techniques.

So we do want to improve the location of the land masses.

SHAPE OF THE EARTH

Another thing we want to do is improve our knowledge of the shape of the earth. For example, we have recently found, utilizing the first Vanguard satellite, that the earth has not a purely oblate shape, sort of like a squashed-down basketball, but actually has somewhat of a pear shape.

Now, these deviations are not large, but they are very significant. For example, this would imply that the surface of the earth is not a

completely plastic structure as has been generally assumed but has some rigidity which has important implications to basic geodetics.

Now, other implications, as a result of the earth's shape, are related to the motion of satellites in orbit, that is, the orbiting characteristics. To illustrate the significance of these considerations, if we neglected the oblateness of the earth in our trajectory calculations, an ICBM could miss its target by 20 miles. Thus the shape of the earth, in general, does influence the motion of the satellite in an important way.

We have to understand the details of how the shape influences the satellite, so that as we go on to more advanced missions requiring prediction of exactly where a manned satellite will be or exactly how to make a rendezvous of one satellite with another, we will be on firm theoretical ground.

GEODETIC SATELLITE

Now, basically the way you utilize the geodetic satellite, is to observe it simultaneously from different portions of the earth or, if the satellite is highly stable and the orbit well known, we can observe it successively and extrapolate its position.

Now, this brings me to a final concluding point: Although we wish to observe the geodetic satellite visually, this satellite has to be a little bit different than the large inflatable balloon I described which would be readily visible. The inflatable balloon is subject to rather large excursions in its orbit due to drag, radiation pressure, and other perturbations. For geodetic satellites we want a very dense satellite which will have a very stable and predictable orbit.

When you try to accomplish this you automatically go to something small, and it is hard to see. So, the geodetic satellite will probably have to have artificial illumination in order for us to observe it.

The navigation satellite which is related in principal very closely to what I have been describing, can use radio observation techniques. This will not give the same positional accuracies as with usual observations, but it may be good enough so that ships eventually will be able in any weather to determine their position with acceptable accuracy by use of such a satellite.

Thank you.

Senator STENNIS. Dr. Dryden, do you have related material now that you would like to present as a companion to this?

Dr. DRYDEN. This goes through the program.

The next one is by Dr. Newell on the scientific satellites.

Senator STENNIS. All right.

May we have questions now? Senator Smith, do you have any questions?

Senator SMITH. I do not have any.

Senator STENNIS. Senator Dodd?

Senator DODD. No, thank you, Mr. Chairman.

Senator STENNIS. Senator Martin, do you have any questions?

Senator MARTIN. No questions.

Senator STENNIS. Senator Cannon?

Senator CANNON. None at this time.

Senator STENNIS. Senator Wiley?

Senator WILEY. None.

TRACKING FACILITIES

Senator STENNIS. I have one for the committee which is from a statement made by Dr. Glennan yesterday, and we will want a reply for the record.

I do not know which one of you wants to answer it.

Dr. Glennan said yesterday:

> Already, the number of satellites and probes required for the presently planned space sciences programs is far larger than was anticipated, even a few months ago, by those concerned with tracking and telemetry reception. Keeping track of the satellites and probes that soon will be traveling across the heavens will tax our operational facilities to the utmost.

It seems that this is pertinent right here.

Does this mean that our space program is going to be hindered by inadequate tracking facilities?

I know you were not talking directly about tracking facilities, but it seems like it would be related.

Dr. DRYDEN. I think if we proceed with the planned coordinated program that this will not hinder us.

There is a question as to the need for tracking everything up there all the time.

The people most concerned with that aspect of it will be those having responsibility for defense, and whether this is a problem or not will depend on how easy it is to distinguish between satellites and ballistic missiles.

Senator STENNIS. What impressed me was that even a few months ago it was so different from what it is now.

Now, a few months from now it could be quite different from what it is as of this date, and thereby you have got the problem of lead time there with reference to your facilities.

Do you view that as a serious matter

Dr. DRYDEN. Yes. There is money for tracking facilities involved in our budget requests.

Senator STENNIS. In the supplemental or in the 1960 request?

Dr. DRYDEN. Supplemental. It is in the supplemental.

It is in the facilities side which we are going to present a little bit later.

Senator STENNIS. All right.

Of course, we will cover those different items in the supplemental budget—we will expressly cover them in the briefing.

We will proceed with the next project here. Thank you very much for your presentation. You will remain with us so that we can go back if necessary.

Dr. DRYDEN. Dr. Newell.

Senator STENNIS. All right, Dr. Dryden. Whom will you call next?

Dr. DRYDEN. Dr. Newell.

Senator STENNIS. All right. Come around by your charts to where you can be seen and heard by all.

TESTIMONY OF DR. HOMER E. NEWELL, Jr., ASSISTANT DIRECTOR FOR SPACE SCIENCES, NASA

Dr. NEWELL. I would like to talk to you about the space sciences program of NASA.

You have heard previously speakers talk about the vehicles that are being developed and the advancing technology that is being developed in our national space program.

These vehicles and advancing technologies give the space scientists powerful tools for space research.

With sounding rockets and satellites and probes deep into space, the scientists can study the earth's upper atmosphere and explore the reaches of space beyond the atmosphere.

In turn, the researcher contributes to the development of those vehicles, lays the groundwork for such applications as those that Mr. Cortright described previously, and contributes to the placing of man in space.

As I go through the discussion, in fact, I shall want to point out to you where some of these applications have come.

Now, when we first came in here, you asked all of us to swear to tell you the truth. One of the difficulties in this discussion is going to be that we do not always know the truth. [Laughter.]

Senator STENNIS. I left out that "whole truth." [Laughter.]

Dr. NEWELL. But we will try to tell you the truth as we see it today, and point out the areas in which we do not know the truth.

SOUNDING ROCKETS

I would like to point out, to begin with, that our space science program had a certain momentum when NASA was formed.

For the past 12 years this country has been using sounding rockets to explore the upper atmosphere.

Perhaps you have not been aware of how large that program actually was. Prior to the International Geophysical Year, which began on July 1, 1957, the United States had fired over 400 sounding rockets to explore the upper atmosphere, to observe the sun, and to carry on special high altitude experiments.

These sounding rockets, however, were confined mostly to the level below 200 miles altitude.

During the IGY an additional 200 sounding rockets have been fired and, of course, it was during that period that we launched our first satellites and space probes.

In discussing the subject of space science, I have divided the subject into a number of areas, but you will see as I go through the discussion that these areas overlap and, in fact, one of the most important parts of space science will be a study of interrelations between the various areas.

Now, as I go through the discussion I will be using these picture charts, and over here I will have a list of the objectives of our space science program. (Chart references apply to chart series 4 in appendix.)

STUDY OF ATMOSPHERES

To begin with, we want to study atmospheres, and we intentionally put that "s" there because we are concerned not only with the earth's atmosphere but also with the atmospheres of the sun and the moon and the planets.

Here are our objectives. I will leave them there for you to look at as I discuss the chart here.

You get some idea of the complication of the subject from the atmospheres chart, and you are already aware of it in connection with the portion of the atmosphere in which we live, which we may call the weather sphere.

We have in it giant circulations, the cyclones, the anticyclones, manifestations of weather like hurricanes and the clouds, rain, hail, and so forth, plus all the intricacies of climate.

Well, the upper atmosphere above the weather sphere also has its complication.

It has its own giant circulations which, at the present time, are not fully understood. So we are bearing down on the problem of learning about those giant circulations.

It has mixing processes, turbulence, and so forth, the same as in the weather sphere.

There are diffusion processes, especially in the upper portion of the atmosphere that tend to separate out the lighter gases with the heavier gases coming down to the lower altitudes.

Thus, we may find that the uppermost portion of our atmosphere consists largely of helium and hydrogen. This is a subject that we are going to look into in our program.

We find that the composition of the atmosphere changes. For example, at 18 miles altitude we find a concentration of ozone, that is, some of the molecules here are made of three atoms of oxygen instead of two as we have down in the weather sphere.

In the higher levels, the oxygen becomes atomic, that is, we have just the oxygen atoms instead of oxygen molecules.

Now, the source of all the activity in our atmosphere is primarily energy from the sun, and we have shown here schematically radiations coming from the sun.

Some of them get through to the earth, some of them are reflected by clouds, some are absorbed in the atmosphere, and some are scattered back out in the atmosphere.

A small amount of energy does come into the atmosphere from the stars, from particles that come into the earth's atmosphere, like cosmic rays and meteors, but by far the largest driving force consists of energy directly from the sun.

The portion of the solar radiation that gets through to the surface of the earth is primarily in the visible wavelengths, some of it also in the ultraviolet and infrared regions, but by far most of the ultraviolet, all of the X-ray radiations from the sun are absorbed in the upper atmosphere and cause many things to happen.

During the IGY, and in the interval preceding the IGY, sounding rocket research gave us a fairly good picture of the atmosphere up to about 100 miles.

However, it did indicate that the atmosphere was highly variable in these upper regions, so that the northern atmosphere is 10 times as dense as the atmosphere over the Tropics.

Also we learned that the properties of the atmosphere vary with time, with season, and time of day, with the solar sunspot cycle.

We do not have the complete picture of these variations, and we must have that picture if we are to understand the atmosphere in its entirety, and if we are ever going to do anything about the weather instead of just living with it.

Our program then will include rocket soundings up to the hundred-mile altitude and way beyond.

It will also include the development of a special sounding vehicle to reach to about 50 miles to study the relations, if any, between this upper portion of the atmosphere and our own weather sphere.

In this project, the development of such a sounding rocket, the Weather Bureau will join with us.

The plan is that in the first portion NASA is going to use this rocket as a fundamental research tool, but after the rocket is developed, the Weather Bureau will take it over as a practical routine observational tool.

IONOSPHERE

Now, part of the atmosphere is called the ionosphere, and when I jump from this picture to the next one, you will note that we change scale. This is 50 miles here.

In the ionosphere we will consider the atmosphere up to a couple of hundred to 300 miles.

The ionosphere is that portion of the earth's atmosphere where some of the molecules have electric charges; the atmosphere is ionized, in other words.

So to the complication observed in the first chart, you will note that we have this additional complication of the ionosphere.

The daytime portion of the ionosphere is illustrated over here; the nighttime portion here.

In general, we recognize several different regions: a D region, an E region, an F region.

In the daytime, the D region can be quite pronounced, while at nighttime the D region, in general, does not exist.

The E region can be divided into two, but at nighttime it is much weaker and it is generally just one layer.

The F region is divided into two, but at nighttime becomes just one layer.

The D region is important to us, that is an understanding of it is, because when there is a pronounced D region we have radio blackouts and our radio communications are interrupted, and this is where the communications satellite will serve us well because when the D region does blackout our normal type of radio communication, we can substitute for the normal type of communications direct contact with the satellites.

The E and F regions are important to us in communications because radio waves of proper frequencies going up to the ionosphere are reflected back to ground; then they may be reflected again to the ionosphere and back to ground, and so on; thus we can communicate around the world because of these reflections.

The ionosphere, in essence, takes the place of the reflecting satellite which Mr. Cortright described previously.

If it were not for the ionosphere these radio waves would have gone straight out into space, and we could not have made the communications beyond the horizon.

In fact, if the frequency of our radiation, our radio waves, gets too high, then the wave still goes on out through space.

Too high a frequency would include, for example, a television wavelength, so that television communications at present must be line of sight communications.

Again the source of energy that produces the ionosphere is primarily the sun, radiations from the sun.

Those radiations that are absorbed in the atmosphere itself, that means X-rays and ultraviolet light, just the wavelengths that we cannot observe at the ground because of the fact they are absorbed in the upper atmosphere, produce the ionosphere.

An additional complication enters in this case because of the fact that particles involved are charged.

This means that the earth's magnetic field affects them.

Any charged particle which attempts to move in a magnetic field is deflected so that if it would like to go this way it finds itself moving in a perpendicular direction, and these deflections cause very interesting motions, current flows, and so forth, that are associated with magnetic effects at the surface of the earth.

In fact, when these current flows get particularly great, magnetic storms on the surface of the earth may interfere with communication lines again.

One of the sources of ionization in the ionosphere is energetic particles coming into the atmosphere.

We depict schematically here a stream of such particles coming from the sun.

On hitting the atmosphere in the northern auroral zones, they give rise to the northern lights, and the problem we are going to attack is to determine the relation between the northern lights, the particles that give rise to them, and the ionosphere itself.

During the period preceding IGY and during IGY itself, sounding rocket experiments gave us a fairly good picture of the ionosphere up to about 60 miles.

A less complete picture from 60 miles to the top of the F region was given, and only a brief glimpse above the F region. That glimpse above the F region, which incidentally was provided mainly by the Soviet satellites, is very tantalizing because we find there is about three times as much ionization above the top of the F region than below, something we did not expect.

This is something we must look into to see what effect it is going to have on communications, guidance, and control problems.

ENERGETIC PARTICLES

I would like to go on to the next subject which is that of energetic particles, and here we show schematically—here are the objectives—three types of such energetic particles: The cosmic rays, the great radiation belt discovered by Van Allen, and, once again, auroral particles.

Cosmic rays are of particular interest because they contain particles of energies much greater than any we can produce in the laboratory.

In fact, in the laboratory we can produce particles of from 1 to 10 billion electron volts.

Now an electron volt is simply the energy that an electron would pick up in falling through a voltage difference of 1 volt.

When you think in terms of billions of electron volts, this means that you put a terrific amount of energy into your particle.

The cosmic rays, however, contain energies of from a million to a billion times a billion electron volts.

Thus they must in some way be very closely related with, intimately related with, some of the most fundamental processes in the universe.

We do not know what they are, but by studying them we hope to get some idea of what these processes are.

We already know that the rays consist of protons primarily, that is, hydrogen nuclei; that there are about 14 percent of helium nuclei, and another 1 percent or so of heavier atoms.

Now the heavier nuclei are of particular importance to the space traveler, to the Mercury project, and future space travel projects, because they are the most ionizing, which is another way of saying that when they go through tissue, they produce a path of ions, they can create damage in that tissue. We must know all about these things in order to evaluate potential hazards.

The Van Allen radiation belt, which is being called the great radiation belt, is of extreme importance also to such projects as Project Mercury.

It consists of particles less energetic than normal cosmic rays, but of so many of them, as many as a hundred thousand times as many particles per unit time per unit area as the cosmic rays, that it constitutes a potential hazard to flight through that region.

We are going to map out this radiation belt to determine what the particles are, to determine what their energies are, and thus lay some of the groundwork for future applications such as space flight.

The auroral particles we are going to ask several questions about. Do they come directly from the sun or do they come from the radiation belt?

Now in all of these cases, the atmospheres, the ionospheres, and the energetic particles, it must have been plain to you that there is considerable interrelation.

The ionosphere is part of the atmosphere; the energetic particles, cosmic rays, the auroral particles come into the atmosphere; the Van Allen radiation belt exists out at the top of the atmosphere and beyond.

There is an interplay between and among these various things which will be an important part of our study of these subjects.

In every case these studies in the vicinity of the earth will lay the groundwork for further studies out beyond the earth.

In the case of atmosphere, ionosphere, and energetic particles, we will want to observe the same things near the Moon and near Venus, near Mars, and the other planets

Our studies, the techniques we develop, will put us in a position to make such observations.

For example, an interesting question will be: Is there another radiation belt like the Van Allen radiation belt around Venus? If there is one, since Venus is closest to the Sun, will the belt be more intense? Will it be a barrier that one will have to get through in order to get to Venus? This is an interesting example.

In the case of atmospheres and ionospheres we have studies that have already brought practical applications and can be expected to bring more.

For example, the past 12 years of study of our atmosphere has laid the groundwork for the present engineering standard atmosphere.

This atmosphere is used in the design of aircraft, will be used in the design for the space vehicles that were described earlier.

In the case of the ionospheres study we have had a very interesting practical result come out of this in the last year or so.

The communications people rely on predictions of what is called the maximum usable radio frequency.

This means when they want to set up a communications schedule between a point, say, in North America and another point in South America, they consult this prediction of what the frequencies, usable frequencies, will be, and they arrange their schedules accordingly.

In the past, this prediction has not always been too good. It has been usable, workable, but not satisfactory.

On the basis of rocket ionosphere research during the past 10 to 12 years, it has been possible to improve that frequency prediction by a factor of three, and we expect that on the basis of future research that improvement will go up.

MAGNETISM, ELECTRICITY, GRAVITY

And now in our next subjects, magnetism, electricity, and gravity, we come to some of the most fascinating subjects to be considered.

We know on a theoretical basis that the shape of the earth's magnetic field out in the space around the earth will be much as indicated here.

However, we also suspect—in fact, we are willing to say we know, except that we ought not to until we make actual measurements—that this magnetic field actually is distorted out here because of clouds of particles coming in, charged particles coming into the magnetic field and disturbing it.

This distortion is important to us from a practical point of view because whenever the magnetic field is distorted, whenever a cloud of particles comes into the magnetic field and causes a change in it we experience a magnetic disturbance on the ground, and this gets in the way of communications again.

With sounding rockets and satellites and space probes, then, we shall study this magnetic field.

We also know that the earth has an electric field, in fact the size of the electric field may surprise you; between the ground and the ionosphere, about a hundred kilometers, there is a potential difference of 290,000 volts.

Of course, you do not notice it here because the difference between ground and a man's head is only a small fraction of the total.

The question immediately arises in the scientist's mind, however, Is there a continuation of that electric field above the ionosphere, and, if there is, what will it do to his space vehicles?

If the space vehicles charge up, what will the charging to to measurements made in those space vehicles? Will his measurements be valid, and so on?

The auroras pictured again here are obviously an electrical discharge very much like the discharge in a mercury vapor lamp.

Well, the question arises, then, Is that discharge associated with a permanent earth's electrical field or is it a temporary field created here, and how is that related to the ionosphere, and again how is it related with communications?

In the field of gravity we have a field that interests the scientists, intrigues the scientists, because we get at one of the most fundamental of the subjects that he can study.

Although gravity has been around for a long time, and we have been using it for a long time, we still do not know what it is. We do not know what causes it. There are many of the laws of gravity that we do not understand.

For example, we have never yet been able to measure any shielding of gravity.

If you take a magnet here and an object over here that would be attracted by a magnet, it is possible by putting a piece of soft iron in between the magnet and this object to shield against that attraction.

The same way if you put a charged body here and another body over here that would be attracted by that, it is possible to shield against that by putting a conducting plate in between.

But if you take two gravitating masses and you attempt to shield, it does not seem possible, at least to the accuracy of the measurements made to date, it does not seem possible to shield against gravity.

Now, why is this? Is it possible that one can, but that we just have not been able to measure it yet, or is it true that gravity just cannot be shielded against?

Another thing, electromagnetic waves propagate with a finite velocity.

It takes a certain time to propagate a radio wave or a light beam from here over to here.

But as far as we know, we have not been able to observe the propagation of any gravitational waves. This is an extremely difficult problem to attack anywhere.

But is it true or is it not, that gravitational waves simply propagate with infinite velocity; that when something happens here then no time later it is felt over here? We do not know.

There is another interesting question. A piece of mass exhibits itself in two ways, two fundamental ways. One, it has this gravitating property that it attracts any other piece of mass.

It also shows up as an inertia. You have to push on it to accelerate it, to make it move. So it shows up both as a gravitating mass and as an inertial mass.

Scientists have long been using the postulate that these two masses are the same, but we do not know that they are the same.

If it should turn out, if we could find out, that they are not the same, then the general theory of relativity does not hold, and Newton's laws must be modified. This is fundamental.

Now, with space probes and satellites we are able to perform experiments on a colossal scale as compared to experiments that we can do in the laboratory. So we have the opportunity, then, of looking into some of these very fundamental things.

I must confess that at the present time we do not know how to solve many of these things, but we, at least, now have the opportunity to think about experimenting in space to solve them.

THEORY OF RELATIVITY

There is one, however, very interesting one that we do know how to tackle, and that is the question of the general theory of relativity.

Senator WILEY. Of what?

Dr. NEWELL. The general theory of relativity. This is Einstein's valuable contribution.

According to that theory—and this is an interesting point—if you place a clock in a strong gravitational field and compare it with another clock in a weaker gravitational field, the one in the strong gravitational field will run slower.

Now, some of the most fundamental clocks are atoms and molecules.

For example, if you want to think of it this way, the biological processes that go on in your body are clocks. So Einstein's theory says that if you live in the basement of a skyscraper, and a friend of yours lives on the top of the skyscraper, he is living faster than you are. [Laughter.]

With satellites we have an opportunity to test out whether this theory is right or not by putting a clock in the satellite and comparing it with one on the ground, and this we are going ahead with.

There is another item here. The distance between the center of the earth from the center of the sun is called the astronomical unit. It has been measured long since, but not very accurately.

We know it only to one part in a thousand. From a practical point of view this means that if we were to attempt a mission to Venus, even with perfect guidance, we could not be sure of getting within 50,000 miles of Venus.

So we must measure this astronomical unit and with space probes we are going to try to do that.

ASTRONOMY

The next subject is that of astronomy.

Astronomy has always, ever since man began to observe the stars, been restricted by the fact that the observer here on the earth is at great distances from the objects he studies.

It has been further restricted by the effect of the atmosphere on the one thing he can get hold of, light from his object of the study.

The atmosphere absorbs a large portion of the light, X-rays, ultraviolet rays, gamma rays, a large part of the radio waves, and so on.

So he makes his observations only in the visible and in some of the radio wavelengths.

Moreover, the atmosphere distorts the light that he gets, so that the usefulness of our 200-inch mirror is limited. It does not do us any good to plan to build a bigger one for observing the Moon because the atmosphere distortion will negate any advantage gained by building the bigger mirror.

With satellites, however, we can get up above the atmosphere and at least eliminate that difficulty, and we are going to build a number of satellites and instrument them to observe in the X-rays, the ultraviolet, the gamma ray region.

The objects of study are the Sun itself, the interplanetary medium, which produces the zodiacal light; we are going to try to study the gas in between stars, the stars themselves, and our galaxy, and other galaxies.

Later, when missions to the Moon and to Mars and Venus are possible we are going to try to study those planets directly.

BIOLOGY

Then we have finally in the subject of biosciences the opportunity in satellites and space probes to study the effects, the psychological effects, of weightlessness, of isolation, confinement and restraint, and the physiological effects of the high energy radiations, the energetic particles, accelerations, noise and vibration, weightlessness, and rhythms.

This is an interesting one: The study of rhythms. We, of course, have adapted ourselves, and so have biological living organisms on the earth adapted themselves, to the day-night cycle.

There are also monthly rhythms and seasonal rhythms, and so on. But a biological specimen or a man put up in a space probe or a satellite will be removed from many of those rhythms.

Perpetual day may replace the day-night cycle in some sections, and so on.

What effect will that have on him physically, psychologically?

I am speaking here of fundamental research, not of the engineering that would go into the man in space project. We are moving ahead to develop a program in this area also.

As the total space sciences program is now shaping up, at the present time it calls for about a hundred sounding rockets per year, and about—well, at least one space probe or satellite every month. This is the size of the program that we are embarking on.

With such a program we will maintain and extend the momentum that we gained in IGY, in the International Geophysical Year.

Our program is also based on broad participation by universities, industry, and research agencies, in addition to Government agencies, including NASA.

Thank you.

INTERNATIONAL GEOPHYSICAL YEAR

Senator STENNIS. Just a minute, before you leave, you spoke of the Geophysical Year. Now what continuing efforts, if any, are there with the Russians since the end of this International Geophysical Year?

Dr. NEWELL. The International Geophysical Year is being followed by what is called the International Geophysical Cooperation during 1959.

The committee that organized and kept the IGY going continues in existence, although its name changes.

The United States has a member on that committee, the Soviets have a member on that committee, so through that committee, and through a continuation of the IGY research we are maintaining cooperation with the Russians in basic research.

Also the International Council of Scientific Unions has created a Committee on Space Research to take over cognizance of this total area, following the IGC 1959.

Senator STENNIS. Do you feel you know the progress they might be making in these various matters that you have been discussing with us?

Dr. NEWELL. Well, I have contacted them about two or three times a year, and in those contacts we have enough discussions so I have a feel for where they are. When they begin discussing problems with which they are struggling, you get sort of a feeling as to just how far along they are.

Dr. DRYDEN. They do not talk rockets, rocket design. They do not talk scientific apparatus and measurements.

Senator STENNIS. Do they give you the benefit of anything they have learned or discovered?

Dr. NEWELL. In the field of space science, upper atmosphere research, and so on, yes; there seems to be a fairly free interchange. The moment we move over toward hardware, like rockets and technology, then we don't get very much.

Senator STENNIS. Do they give an explanation for that?

Dr. NEWELL. They say simply that we do not need to know that in order to benefit from the other.

Senator STENNIS. All right. We will have questions.

Senator Smith?

Senator SMITH. No, Mr. Chairman. I think this is of tremendous interest and there are many, many questions and hours of discussion that can come out of it.

It seems to me it is very important for the committee to get all of these statements, and then move into questions because of the interesting things; so I will delay my questions for the time being.

Senator STENNIS. Thank you very much.

Senator DODD?

Senator DODD. I feel as Senator Smith does, except I am curious about one thing in something you said. I do not know whether it will help us very much, but it will help me to understand it.

In the basement or the penthouse where you have those men, does this mean that would have an effect on aging?

Dr. NEWELL. Yes; theoretically, but the difference in that short distance is immeasurable.

Senator DODD. I know that. What I am looking to is the fellow who gets way out, will he live longer?

Dr. NEWELL. Theoretically; yes.

Senator DODD. That could have a great effect on our living. [Laughter.]

Senator STENNIS. Senator Martin?

Senator MARTIN. No questions.

Senator STENNIS. Senator Wiley?

Senator WILEY. I have no questions.

Senator STENNIS. Senator Cannon?

Senator CANNON. No questions.

Senator STENNIS. Well, it is 12:25 now, and I imagine your next presentation would require several minutes anyway.

Could the committee and the witnesses be back at 2 o'clock?

Without objection then the subcommittee will take a recess until 2 p.m.

(Whereupon, at 12:25 p.m. the subcommittee recessed to reconvene at 2 p.m. the same day.)

AFTERNOON SESSION

Present: Senators Stennis (presiding), Dodd, Cannon, Wiley, Smith, Martin, and Case of New Jersey.

Senator STENNIS. The committee will please come to order.

The testimony this afternoon will be continued and at the end of the briefing we will have an executive session.

I believe that it would be better for you to proceed now, Dr. Dryden, with several of your presentations without stopping for the usual questioning; and then after you have presented this picture, everyone will have full opportunity to ask questions.

So, without objection, we will ask Dr. Dryden to proceed.

Who do you have next?

Dr. DRYDEN. Mr. Wyatt is the next speaker on advanced space missions.

This is getting into the future, Senator Wiley, quite a bit.

TESTIMONY OF DeMARQUIS D. WYATT, TECHNICAL ASSISTANT TO THE DIRECTOR OF SPACE FLIGHT DEVELOPMENT, NASA

Mr. WYATT. Ladies and gentlemen, the preceding speakers have discussed some of the programs that are part of the total NASA space flight program.

Dr. Silverstein, in his presentation, discussed the need for and the kinds of advanced boosters that we have included as part of our total program.

In this presentation, I would like to go into a cut in depth on a couple of program areas to show you both the kind of logical program development that we may expect to take place over a period of years, and to show how that kind of program development is intimately related to the booster capabilities that we desire.

SPACE PROGRAMS

On this first chart I have simply restated the elements of the comprehensive kind of a space flight program which we in the NASA feel is essential to a vital total national space research program. (Chart references apply to Chart Series 5 in appendix.)

There are any number of ways you could break the total programing down. Here I have chosen to do it in terms of those programs related to earth satellites, those related to lunar exploration, planetary exploration, and finally solar probes.

Dr. Newell, in his presentation, discussed the objectives of such things as solar probes, probes and orbiting vehicles around the planets and around the moon, and the directions and objectives of our scientific satellites around the earth.

Mr. Cortright, in his presentation, discussed some of the applied satellites, that is, the communication and meteorological satellites.

I should like to review the kind of a development sequence that we can foresee in the field of orbiting laboratories, and then I shall take up the development of the field of lunar exploration.

If man—and not "if," because man will fly into space—there are, as Dr. Dryden has indicated in his oral testimony, a number of things that we must find out.

We have to find out factors that affect the biological process, the living organism of man himself; how he reacts to this space environment; which is a very alien environment as compared with this atmosphere that we live in.

Furthermore, we must ascertain before we send a vehicle into space that it is as nearly a perfect piece of mechanism as anything man has ever built; because, once you launch a spacecraft with a man in it in the direction of the moon or of any planet, everything has to work. You do not turn around simply and come back if something fails. You do not drift and eventually drift to a friendly shore. You obey the immutable laws of motion and you tend to go out.

So we are going to have to ensure to the highest extent possible that every piece of equipment that we put in the craft is proven and capable of working for the months or even years—in the case of some planetary expeditions—that will be required.

There are two ways you can do this, and we shall use both of them:

We shall utilize facilities, research facilities, on the ground so far as possible, both to study the effects of simulated environments on man and on the technological articles; but this total space in which we must fly has vacuums that are very difficult to achieve completely upon the earth.

It undergoes radiations, particle encounters, micrometeorite encounters, a great number of factors that will be difficult to represent in whole in an earth laboratory.

Hence we feel that an integral part of the total space exploration and research phase is going to be the placing of satellites in orbit about the earth that are actually flying in the total-space environment that we are going to have to encounter, and in which we can study both the biological and technological processes involved.

SPACE LABORATORY PHASES

A space-laboratory program, therefore, falls into a sequence of phases. It depends upon our objectives and upon our capabilities.

For example, already, in the development of the ballistic missiles, they have actually been used as space laboratories of sorts in several instances.

The armed services in some of their nose-cone experiments have put first a mouse and then a monkey—instrumented to record their reactions to the launch, brief space flight, and reentry processes, and the data obtained from these kinds of flights have been very valuable in ascertaining the physiological effects of these sequences of events on animals.

Unfortunately, the animals were not recovered; so that postflight examinations and comparison with the preflight condition was not possible. But, nonetheless, we learn a rather large amount by such simple experiments.

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The next phase is going to occur in the Air Force "Discoverer" program, which is expected to start momentarily, in which they, too, will use small animals for experimental purposes, but they will orbit the earth and be recovered.

When we come to the Project Mercury, discussed by Dr. Dryden, a project involving the placing of a man in orbit for one or more passes up to about a 24-hour maximum, we will, from a space-laboratory viewpoint, have made a very significant step forward; because first we can put the most important subject of all, man, into the space environment, and secondly, we can keep him there for relatively long periods of total immersion in a weightless space condition as compared with any other kind of experiment that we have been able to conduct to date.

Even the X–15, as Dr. Dryden noted, will enable us to put a man up for only 4 or 5 minutes in a weightless condition.

Here we will have the capacity to put him, as the program develops, up to perhaps 24 hours. So we will have a significant step forward when we have the 24-hour satellite represented by Project Mercury.

Of course, as Dr. Dryden indicated, before man himself flies, we will have studied the physiological effects of flight on animals.

Valuable though this information is going to be, it will not answer by any means the many questions that we need to know before we put man into a truly ambitious flight out to the Moon or out to nearby planets.

For example, the psychological effects of isolation will be relatively low, because he is only going to be up for a few hours to a day. We are not going to have an adequate, a completely adequate opportunity to determine the effects of external stimuli such as heat, light, and noise on the long-term reaction of a human being. And, perhaps most importantly, this is not going to give us the kind of a technological platform we need to evaluate life-support systems—that is, that system which we carry along in order to supply a usable atmosphere within the vehicle.

As Dr. Dryden indicated, this vehicle will permit us to carry oxygen bottles and we will replenish the atmosphere.

But when we think of long-term flight, it becomes prohibitive to carry enough oxygen with you, and you are going to have to make self-contained apparatuses that replenish the atmosphere, restore it to a usable form. And in Project Mercury, because of the technical limitations of the weights we can put up with the available boosters, it will not be possible to do that. Hence, we look ahead to the next phase in the orbiting laboratory, one in which we can put more than one man for a period longer than 1 day.

Now, we indicate here that as an objective we might try to put two or more men for as much as 3 months for a long-term study of their actions and psychological and physiological reactions to this space environment for this long period.

We cannot do this, this next step, with our present booster systems. We will have to have the next phase, at least the Vega and probably the Centaur class of booster before we can put up a large enough vehicle to contain the life-support systems and all of the equipment that we would desire to sustain a man here for a period of from days to weeks and perhaps on into months.

This will again yield a great deal of information, but, from certain technological aspects, if we are going to send a vehicle out to Mars, say, eventually, we are going to have to have equipment that will operate continuously and reliably for periods upwards of years—a year or two—and we need a platform in which we can run technological investigations of the effects of space flight on such things as electronic communication systems, on materials themselves over an extended period of time.

Hence, we feel that we need to go beyond this temporary sort of a space laboratory, and will eventually want a permanent laboratory to which we can take men up and back.

We would not expect to keep the men up there permanently, of course, but have the laboratory itself going on, and we would resupply and reman it as the occasions warranted.

Now, to do this, to get a permanent laboratory of a useful size into orbit, we are going to have to have the very large booster engines, the sort discussed by Dr. Silverstein.

PERMANENT SPACE LABORATORY

On the next chart I illustrate—and this I want you to understand as a speculative sort of illustration—what such a permanent laboratory might look like.

The one I have shown here is something that technologically, could be launched by the 6-million-pound booster engine or booster vehicle, the Nova that Dr. Silverstein discussed.

It could be a rather large laboratory. It could have the working volume of a small- to medium-sized house. It might be of the order of 12 to 20 feet in diameter, 80 to 100 feet long; and while it is impossible at this time to state what would exactly be in such a laboratory, I have sort of made a potpourri here of a number of things that we might want to carry on simultaneously in such a laboratory.

In the first place, when we launch this, it would be drawn together; it would be launched into orbit, and then—because we would probably want to have an artificial gravity to get away from the weightless condition over a long period of time—we would begin to spin that at about this axis. We do this by means of control jets at either end.

That would give it a motion such as this [indicating].

In so doing, we would create an effective gravity that would increase as we moved from the center of rotation.

Now, in order to reduce the simple spinning effect, the potential dizziness that comes from simply spinning around, we would want to spin this as slowly as possible to get the desired gravitational level; and, hence, we visualize that we might design our system so that it actually could separate a little bit via a connecting tube—increase its length—and thereby we could reduce the rate at which we would have to spin it to get this desired gravitational level.

We further indicate that only approximately half of this would perhaps be pressurized and sustained at an atmospheric condition where man could live and work without wearing a spacesuit.

You will notice here, incidentally, that there are men represented in a wardroom at the end and working at this end, and they appear to be standing opposite one another. That is because the only gravity that they feel is that induced by spinning, and this man feels gravity—

actually, a centrifugal force—that tells him "down" is at that end of the vehicle. These men [indicating] feel a force which says "down" is at this end of the vehicle. And of course when you get right in the center, you would have a weightless point.

Now if we didn't spin this vehicle, we would have an entirely weightless condition and the men and all free articles would simply float around without any orientation or any pull in any direction.

Because, for psychological purposes, it would be desirable to give the living quarters the most earthlike atmosphere or condition that we could, likely we would have the crew quarters at the extreme end where they would get the most nearly accustomed force of gravity. But then, as we proceed "up," we may have here a biological laboratory using small animals to study the effects of varying space conditions on the life processes of small animals.

Next, we might have a simple microbiological laboratory in which we would study the very fundamental forms of life, the fungi, the viruses, and this sort of thing.

Then we might have a section—and, again, recall this is a hypothetical group of experiments that we might put together—we might have a physics and astronomical unit.

We could do this closer to the center of gravity, because the gravity is not as important in these experiments.

Now, as I indicated, this whole end of the vehicle would be pressurized [indicating].

Over here [indicating], we illustrate the technological end of the vehicle. Here is where we are doing experiments on things, on materials, on communication systems, on the various elements that must work and which we must find out have a highly effective useful life. This would also be the power section, supplying the power to sustain and operate this whole vehicle. We do not contemplate that it would be necessary to create a natural environment here, but that the dwelling times of man in this section would be small enough that he could wear his spacesuit and carry just a local environment in order to set up and check on his experiments and to service the equipment.

Here [indicating] we may have, for example—this simply indicates panels in which we might be exposing various materials to the micrometeorites encountered and the particle bombardments to find out the effect of total-space conditions on material.

Up here [indicating] might be a cluster of solar cells for collecting solar energy, converting it to electricity for storage in batteries from which to power all of the equipment in here.

Now, because this is visualized as a permanent laboratory, of course we have to have some means of remanning and resupplying it over a period of time; and, hence, we illustrate up here a hatch and a connection mechanism by which we would make close rendezvous and bring in the supply vehicles which would then depart back to ground stations.

Now this is—as I indicated and as I must emphasize—not something that is under detailed design; but it is conceptual of the sort of thing that we think we will eventually arrive at in terms of the orbiting space laboratory.

The information that we learn from experiments conducted in laboratories of this sort will be vital to the successful accomplishment of really ambitious missions such as a manned flight to the moon.

LUNAR EXPLORATION PHASES

Let us consider the sequence that lunar exploration might take; it is illustrated here [indicating].

Already, of course, we have in this country launched several probes toward the moon. The Russians have launched a probe which actually got by and went beyond the moon.

We shall be launching unmanned oribiters, that is, instrumented vehicles that will go out and become satellites of the moon that will enable us to determine scientifically the conditions in the vicinity of the moon.

Our next step shall be to try to attempt landing instrumented packages on the moon for the purpose of exploring the moon's makeup itself.

These can be of two classes: What we call a hard landing and what we call a soft landing.

A hard landing is to permit the vehicle to come in with a projectile-like velocity and impact, get data right down to the moment of impact and, under certain favorable conditions, perhaps continue to collect data after the impact is made.

But we are much more interested in the so-called soft landing. This means we have to spoil the velocity of the vehicle as it approaches the moon and allow it to set down with what I should call essentially zero contact velocity, actually bringing it down at no more than a couple of hundred feet a second; so that by suitable cushioning, shock-absorbing mechanisms, we can take up the landing shock and still maintain the instrument package intact and working.

Now, unfortunately, to make a soft landing means that we must carry a rather sizable rocket all the way from the earth out to the moon and then have reversed the vehicle so that we fire the rocket in opposition to the vehicle's flight.

In other words, if the vehicle is flying this way [indicating], we fire the rocket out [indicating].

This is the meaning of the word "retrorocket." There is a retro-active thrust opposite to the direction of the motion. In so doing, we gradually slow the vehicle down.

Now this rocket to slow the vehicle down has to be rather large, and it means that much of what could be payload capacity for an orbiting vehicle has to be used simply as a retrorocket, and in fact we find that for a given weight launched from the earth, we can only have an instrument payload about half as big for a soft landing as we can have for a simple orbit around the moon.

In other words, we use up about half the useful payload in slowing it down. This means we have to have rather large boosters if we are to carry a useful sized payload out to and land it on the moon.

Now, so far, I have talked only about instrument flights.

We then come to the point of putting a man in orbit around the moon and then returning him back to the earth.

To do so, we know that there are certain minimum package weights that we can put around the man to sustain his life process and to bring him back. We are going to have to shoot for fairly large boosters.

We might be able to accomplish this mission minimally with the million-pound clustered engine.

But when we talk about landing a man on the moon and bringing him back to the earth, we have to begin talking about the 6-million-pound and larger booster engine.

On my next series of slides, I am going to illustrate some of the elements of a hypothetical mission to the moon involving a man, simply to show from a vehicle viewpoint what is required.

LAUNCHING FROM EARTH

We start off with this 6-million-pound booster, although this doesn't show the multiple cluster of engines. It represents a booster capability of 6 million pounds and would have to be about 300 feet high.

The man would be contained in the capsule up under the aerodynamic fairing—at the nose of the vehicle.

To accomplish this particular mission, we think the vehicle would have to have seven successive firing stages; whereas, the Vanguard has three stages of rockets. This would require seven.

We would fire the first four stages in sequence, in order to acquire the necessary velocity to carry us out to the moon orbit, to the moon itself, and so we would arrive in the vicinity of the moon having expended four of our seven rocket stages.

In the process, also, as somebody inquired yesterday about the Vanguard, once we got outside of the earth's atmosphere, in order to drop the weight to the minimum value so that we don't carry any spare weight, we would blow off the nose-cone fairing and expose the capsule that we finally want to take to the moon.

INITIATING LUNAR LANDING

Hence, when we get to the vicinity of the moon, we might have something that would look like this [indicating], where we have now turned this around and it is going backward, so to speak, and is in its landing attitude.

Now, down here [indicating] on the ground, I show something that has already alighted.

Before we get to the point of landing a man on the moon, it will have been necessary to demonstrate our capacity to control the landing of instrumented objects at preselected points on the moon. You wouldn't want to land on the side of a crater, for example; so, it would be necessary to go through this technological process first, and then we would probably land a beacon on the surface of the moon to guide in our manned ship.

In other words, the radio beacon would be down in a desired landing place, and it would give guidance instruction to this vehicle to bring it in and land it at the point we want.

Now, here you see [indicating] the rockets firing to reduce the velocity of this vehicle as it approaches the moon's surface. We would actually include some form of shock-absorbing legs so that when it sits down—you don't expect to find a flat table-top surface—it could adjust itself into a vertical position to be ready for return to the earth.

TAKE OFF FROM MOON

The next chart shows the configuration taking off from the moon. The base upon which we landed containing the retrorockets that cushioned our fall would remain behind. It is of no more value to us, and we don't want to carry that excess weight back.

Instead, we launch now the basic capsule which would contain the man, by means of a single-stage rocket. We build up his velocity, and there is not nearly as high a velocity this time, to start him back on his path to the earth.

It will be necessary to apply midcourse guidance.

In other words, we will have to carry this rocket along for quite a distance so that as we get closer and closer to the earth, we can correct the path of this thing; because it is very critical to bring this in at the right grazing angle to the atmosphere of the earth, so that we neither come in and hit too hard or just skip off the atmosphere like a stone skipping on water and go bouncing back into space. So, we carry this rocket along to give us some midcourse guidance—this, or some other rocket.

But this, you see, is a gradually diminishing piece of machinery from what we started off with.

RETURN TO EARTH

Here [indicating] we are with the vehicle making its retrodescent back into the earth. This now begins to look like the Project Mercury capsule that was illustrated here [indicating], but here the rockets are still firing to slow it down for this final pass through the earth's atmosphere for recovery.

We start off with about something over 4½ million pounds in the launching site, the launching stage that sits on the ground. We come back with no more than 2,100 pounds that we can place back on the surface of the earth. Twenty-one hundred pounds is about the minimum that could support and sustain a man for the several-days-to-a-week journey that I have illustrated; and to get this ton back, we have had to start with at least a 4½-million-pound load in leaving the earth.

So, you see, to talk about landing a man on the moon and bringing him back without simultaneously talking about the very large booster engine makes no technical compatibility.

Now, the flight of this sort, landing a man on the moon and returning him, is not simply a matter of course of getting advanced propulsion systems. We are simultaneously going to and are carrying along programs to greatly improve our guidance, both the insertion guidance—that is, that phase when we kick out of the earth's atmosphere and go into our trajectory to the moon—the mid-course guidance that corrects our course to the fine point, and the terminal guidance that brings us down to the point on the moon. These elements all have to be studied.

The communications system, because as we get out we are limited in the amount of power that we can carry in the form of batteries or solar cells or any other form of power, we must extract from the power we use the utmost utility. We have got to cut the power down to the very least that we possibly can in order to communicate back to the earth. We have got to work in communication areas.

We have got to work in a vast number of supporting technological areas, and these programs must go along simultaneously with the improvement in boosters.

Senator WILEY. With what?

Mr. WYATT. They have to go simultaneously with the improvement in the boosters, the booster vehicle.

In other words, we have to develop boosters and we have to develop a lot of other equipment at the same time we are going ahead.

Now we are starting studies aimed at the elements of the design and the problems developed in flights such as these. They won't take place for a good many years, but we are starting in with programs of study now so that we can block out and work on, as we go, all of the major problems.

But I would leave with this point: that these studies, no matter how elaborately, and no matter how far they are carried along, are going to mean nothing unless we have a concurrent development of these very large boosters; because that is the key to the whole situation for this advanced mission into space.

Thank you.

Senator STENNIS. Thank you very much.

Now, Doctor, do you wish to proceed with another witness?

Dr. DRYDEN. The next speaker is Dr. Silverstein on facilities for the space program.

TESTIMONY OF DR. ABE SILVERSTEIN, DIRECTOR OF SPACE FLIGHT DEVELOPMENT, NASA

Dr. SILVERSTEIN. Mr. Chairman, with your permission, I will take from our book here only the facilities and try to go through it as fast as I can.

Senator STENNIS. All right. You have plenty of time. Do you want us to refer to our books now?

Dr. SILVERSTEIN. Yes.

The facilities we are requesting in the 1959 supplemental request amount to $24,250,000.

Dr. DRYDEN. Page 303.

Senator STENNIS. Oh, yes. It is this book.

Dr. SILVERSTEIN. The green book, page 303.

Senator STENNIS. Thank you, sir.

Dr. SILVERSTEIN. Does everyone have a green book?

CONSTRUCTION OF EQUIPMENT

You will find here a summary of the 1959 supplemental estimates for construction of equipment, consisting of three items: one for $9 million for the facilities at the Jet Propulsion Laboratory which were discussed yesterday by Dr. Glennan and Dr. Dryden; an item for $12 million for tracking facilities; and an item of $3,200,000 for propulsion development facilities.

I would like to read briefly to provide a description and justification for these facilities, page 304:

JET PROPULSION LABORATORY

The Government-owned property and equipment of Jet Propulsion Laboratory (JPL) of the California Institute of Technology near Pasadena, Calif., was transferred to the NASA by Executive Order 10793, dated December 3, 1958. In the past, JPL has done outstanding research and development work in missile, satellite, and space-probe fields through its contributions to the areas of solid propellant rockets, guidance systems, and electronic instrumentation, communication, and tracking systems. The NASA expects to rely heavily on JPL in the future for further advanced research and development in all of these areas in support of the national-space program.

JPL was established before safety codes dealing with liquid and solid rocket propellants were established. Subsequent safety code standards have made most of the rocket test facilities at the Pasadena site nonconforming. At the present time all but 10 of the 92 facilities on the laboratory site are operating on safety waivers. These waivers make it illegal to modify the existing facilities to meet changing needs and thus severely restrict the potential future effectiveness of the laboratory. The effectiveness of the laboratory is also limited by inadequate vehicle assembly areas, guidance laboratories, and supporting facilities.

This project covers the modernization and expansion of facilities at JPL to provide for a strengthening of its research and development support of the NASA space program. Acquisition of a site of approximately 60 acres is required to permit the relocation of various rocket test facilities and associated equipment to a nonhazardous location where safety code standards can be met. Another site acquisition of approximately 7 acres, currently under a rental agreement, is needed to provide for future expansion. Roads, water, and other utilities to service the new areas will be required. A new substation and transformer-bank addition will be necessary to provide power for the proposed facilities.

Now, if we go over to page 311, you will find a summary of the costs of the facilities, and they show that for the land acquisition there is a sum of $375,000.

Senator STENNIS. That is page 311?

Dr. SILVERSTEIN. 311.

Senator STENNIS. Mr. Reporter, put pages 305 and 307 through 310 in the record at this point.

(The pages referred to are as follows:)

In addition to the relocation of test facilities, the project includes the construction of a vehicle assembly building, the expansion of the guidance laboratory, and the modernization of several existing supporting facilities.

The present layout of the jet propulsion laboratory and the proposed land and facility additions are shown on the site plan on the following page. Descriptions and justifications of the various items that comprise this project follows:

LAND ACQUISITION

The present jet propulsion laboratory comprises some 80 acres, of which approximately five are leased from the city of Pasadena. This existing acreage is shown as zone I on the site plan.

Acquisition of 60.37 acres (zone II)

The Ordnance Department has secured a condemnation lease on approximately 60.37 acres of land north of and adjacent to the present JPL property line. This lease was taken to prevent the utilization of the land for a housing development which would have forced the suspension of all rocket test work at JPL. This area is shown as zone II on the site plan. The land will be required for the relocation of existing rocket test facilities from zone I in order to permit their modification and expansion for advance research and development programs. The topography of the land is such that the proposed relocation can be accomplished to comply with all existing safety requirements.

Acquisition of 7.19 acres (zone III)

There are another 7.19 acres of privately owned land contiguous to the southern boundary line of the existing laboratory. This land is designated zone III on the site plan. At present this area is under a least which expires July 1, 1959, and which the owner does not wish to renew. Other contagious sites are rapidly being developed, and there is every reason to believe that this development will continue. Unless the proposed site is acquired it will undoubtedly be developed for other purposes, and further expansion of the jet propulsion laboratory will become unduly expensive or be prohibited altogether. The proposed site is necessary to the future expansion of the laboratory. and its acquisition at this time is considered to be a prudent and economical investment.

UTILITIES

Relocation area utilities

In order to provide access and utility services in zone II to the relocated facilities, it will be necessary to construct roads and extend and enlarge the utilities

systems now serving the existing laboratory facilities in zone I. The new land to be acquired is completely undeveloped, and is not adjacent to any public utility system.

It is planned to construct a central utilities plant to house the equipment and machinery required to operate and control the various utility systems. This building will be of frame and stucco construction with a total area of about 5,000 square feet including a small shop area.

New substation and transformer bank additions

The present substations and transformer bank are insufficient to provide power for the proposed facilities. Additions to the electrical system will be necessary to meet the new requirements. These additions will include a unit substation for transforming 16.5 to 2.4 kilovolts for local distribution, feed lines to the substation from the existing high-voltage supply, and an electrical distribution system to the new facilities.

RELOCATED TEST FACILITIES

A number of rocket test facilities and their associated equipment will be placed on the zone II site. These will replace existing facilities now located in zone I and operating under safety waivers and exemptions.

Solid propellant processing laboratory

This project includes a building of approximately 1,200 square feet of frame and plaster construction that will be used for shop and laboratory facilities; a building of approximately 4,000 square feet of reinforced concrete construction providing space for mixer, grinder, storage, and preparation rooms; and a mezzanine of approximately 1,200 square feet for necessary air conditioning and refrigeration equipment. Complete air conditioning, constant temperature, and humidity controls are essential for operation.

Solid propellant test cell and control building

This facility consists of two test cells (468 square feet each) and a control building (2,667 square feet). The test cells will be heavily reinforced concrete, earth covered structures; a concrete pad with protective steel screen supported by steel frames will be provided at the firing end of each cell. Concrete mounting and thrust blocks will be designed to withstand 20,000 pounds of thrust. The control building will be of reinforced concrete and frame and stucco construction. The building will contain a control room, motor assembly shops, and laboratories.

Solid propellant test cell

A third test cell similar to the cells in the previous item will be constructed. It will include its own control building, but will utilize the laboratories provided in the previous item. The three test cells provided in these items will replace four test cells which are presently in violation of the safety code.

Solid propellant hazardous material storage magazine

This facility will provide for storage of hazardous solid propellant materials necessary for the development of rocket motors in the solid propellant engine program. The facility will consist of 2 reinforced concrete buildings with 16 individual earth-covered cells. The blowout wall on the road side of the buildings will be wood frame, dry wall type construction. Earth barricades will be required around this facility. This project will complete only a portion of the necessary storage facilities. The design will permit later addition of 24 additional storage cubicles.

Solid propellant chemistry processing laboratory

This facility is required for research and development on improved solid propellant materials. It will comprise approximately 2,000 square feet in a building of concrete block and reinforced concrete to house a propellant chemistry laboratory. In addition, there will be a 500-square-foot enclosure housing grinder, blender, curing, surge, and charge rooms. This enclosure will have 3-foot reinforced walls for blast protection.

Liquid propellant test cell and control building

This facility consists of a twin mount, reinforced concrete test cell (462 square feet) and a one and one-half story control building (4,158 square feet). The control building includes a central recording station, laboratory, security control room, and control room. A part of the building will be reinforced concrete, and

the remainder frame and plaster construction. Some special lighting and air conditioning will be required in the control rooms, and 40 kilowatts of electrical power will be required.

MODERNIZATION OF EXISTING SUPPORTING FACILITIES

The expansion of several supporting facilities has not kept pace with the overall laboratory expansion. As a result, the technical effectiveness of the laboratory is being diminished by the use of marginal, and, in many cases, completely inadequate supporting facilities. In order to improve the efficiency and scope of operation of the laboratory, it is necessary to add to and modernize certain of these facilities.

Completion of guidance laboratory

The success of future satellite and space probe missions will be critically dependent upon the accuracy of the guidance system. The Jet Propulsion Laboratory has had considerable experience in the field of guidance systems for missiles and is expected to play a prominent role in the development of advanced systems future space flight applications. The existing guidance laboratories at JPL are inadequate to conduct the necessary research and development. The proposed facility addition will provide the requisite laboratory space.

The facility will consist of a three-story wood and stucco structure totaling 42,366 square feet, fully air-conditioned, and provided with the special electrical service needed in the development of guidance equipment. This building will house a complex of laboratories and offices. The increased area will accommodate the following functions: Reliability research, solar battery research, component evaluation, information theory, infrared research, photo sensitivity research, inertial component laboratory, gyro research laboratory, optical component laboratory, transducer laboratory, tracking filter development, microwave component laboratory, new circuits laboratory, guidance computer laboratory, optical track laboratory, radio guidance, radio astronomy, stockrooms, service shops, and utility rooms.

Missile engineering building

The present missile engineering building was constructed in 1957 but was not completed to the known requirements. The proposed facilities will include an addition to the east end and a third floor addition to the central portion of the present building to provide 13,000 square feet of office space. Both additions will be of stud and stucco construction.

Plant services engineering building

The proposed addition to the present building will provide approximately 14,000 square feet of office space to relieve the present over-crowded conditions in a building presently housing the design, engineering, and supervisory personnel of the plant services department as well as supervisory personnel of the test mechanics services department.

Administrative services building

This facility will be an addition to the west end of the present building. It will provide for expansion of the property receiving department and of the proofing and accounting departments. This addition will also provide more work space for the inspection and quality control departments, mailroom, and shipping department. The addition will be of stud and stucco construction.

Carpenter shop building

This facility will be a two-story steel frame building with stud and stucco walls comprising an area of 8,500 square feet. It will replace the old carpenter shop which was recently torn down, and will provide space for the new carpenter shop and for lumber storage.

Plant services building

This facility will be an addition of approximately 10,000 square feet to the existing plant services building. It will be necessary to tear down parts of the present building for this construction, which will be of stud and stucco. The ground floor will contain shops for the electrical and mechanical groups of the plant service department. The second floor will contain offices for the electrical and mechanical department.

NEW SUPPORTING FACILITIES

Vehicle assembly building

At the present time, facilities for assembling complete vehicles at JPL are entirely inadequate. The present area is so congested that final checkout is done out of doors. The crowded conditions within the building and the inclement weather during outside operations seriously hamper the work. The proposed facility will move all operations indoors and will permit the assembly and checkout of several vehicles simultaneously. The proposed building consists of a vehicle assembly area of 18,700 square feet, an electrical test area of 15,400 square feet, mechanical and electrical supporting work areas of 20,300 square feet, and an upstairs office and laboratory area of 8,100 square feet. The assembly areas will have 50-foot ceilings of hangar-type construction, and other areas will be wood frame and plaster. Office areas and laboratories will have wood and linoleum floors and acoustical tile ceilings. Air conditioning is necessary for temperature and humidity control.

Reports and periodicals building

The proposed facility will be a Butler-type, prefabricated building of approximately 7,000 square feet to house the activities of the technical reports section until such time as a combined graphic arts building can be provided.

Dr. SILVERSTEIN. Page 311 shows a sum of $375,000 for land acquisition.

On page 312, total utilities of $2,950,200; page 314, total relocated test facilities summarized at 2 preceding pages to the amount of $1,931,800.

Senator STENNIS. Pardon me just a minute.

Mr. Reporter, put pages 311, 312, 313, and the top half of 314 in the record at this point.

(The pages referred to are as follows:)

2. Cost estimate

Land acquisition:	
Acquisition of 60.37 acres (zone II)	$300,000
Acquisition of 7.19 acres (zone III)	75,000
Total, land acquisition	375,000
Utilities:	
Relocation area utilities:	
Central utilities plant including boilers, water chillers, water treatment plant, air compressors, electrical switch gear, and miscellaneous items	784,800
Roads	500,000
Drainage	104,000
Fencing	36,000
Steam distribution system	186,000
Chilled water distribution system	210,000
Water distribution system	216,000
Sanitary sewer system	28,300
Compressed air distribution system	29,600
Gas distribution system	9,500
Electrical substation system	384,000
Street lighting	35,000
Design, engineering, and contract administration services	252,000
Total, relocation area utilities	2,775,200

2. Cost estimate—Continued

Utilities—Continued	
New substation and transformer bank addition:	
Unit substation, 2,500 kv.-a., 16.5 kv. to 2.4 kv., including voltage regulation	$100,000
16.5 kv. feeder line to substation	10,000
Tieline to existing system	20,000
Underground feeds and ducts	45,000
Total, new substation and transformer bank addition	175,000
Total, utilities	2,950,200
Relocated test facilities:	
Solid propellant processing laboratory:	
Building and equipment	271,000
Site preparation	5,400
Paving	1,400
Building utility services	14,600
Barricades	16,000
Retaining walls	24,000
Design, engineering, and contract administration services	51,000
Total, solid propellant processing laboratory	383,400
Solid propellant test cell and control building:	
Instrumentation and laboratory building	43,500
Test cell control room, motor assembly, and preparation shop building	72,600
Test cells	48,600
Retaining walls	14,000
Paving	1,000
Site preparation and excavation	65,500
Barricades	2,800
Utility connections and trenches	13,000
Electrical substation	14,300
Design, engineering, and contract administration services	28,100
Total, solid propellant test cell and control building	303,400
Solid propellant test cell:	
Test cell	35,100
Control building	54,600
Steel netting	2,300
Retaining wall and slab	10,000
Supporting facilities	12,000
Instrumentation	35,000
Miscellaneous equipment	15,000
Total, solid propellant test cell	164,000
Solid propellant hazardous storage magazine:	
Two buildings	125,000
Barricades	16,000
Utilities, including humidity and temperature controls	106,000
Total, solid propellant hazardous storage magazine	247,000
Solid propellant chemistry processing laboratory:	
Building	468,000
Miscellaneous equipment	40,000
Total, solid propellant chemistry processing laboratory	508,000

2. Cost estimate—Continued

Relocated test facilities—Continued	
Liquid propellant test cell and control building:	
Control building	$114,700
Test cell	42,700
Site preparation and excavation	65,500
Building utilities	9,100
Fuel tanks	12,000
Nitrogen cascade	26,300
Electrical substation	18,200
Barricade	7,000
Design, engineering, and contract administration services	30,500
Total, liquid propellant test cell and control building	326,000
Total, relocated test facilities	1,931,800

Senator STENNIS. Doctor, do you want to indicate the high points here? You have already read part of it, but if there are any other material points we think this is the place for you to cover those.

Dr. SILVERSTEIN. Fine. I will do that.

You will notice in these pages 312 and 313 a description of the relocated test facilities which are largely the solid propellant and liquid propellant test stands that need to be relocated so as to provide safe conditions for the personnel operating the laboratories.

On pages 314 and the top of 315, we find modernization of existing supporting facilities, including the completion of the guidance laboratory where the laboratory is working on items such as were described by Mr. Wyatt in his last presentation—the terminal and mid course guidance systems of our lunar flights—the Missile Engineering Building, which, in a sense, is the building in which assemblies will be made and engineering performed on vehicles for space flights; adding up to a total of $2,255,000 shown on the top of page 315.

Senator STENNIS. Right at that point, Mr. Reporter, include that item which is covered by the bottom part of page 314 and the top third of page 315.

(The sections of pages referred to are as follows:)

Modernization of existing supporting facilities

Completion of guidance laboratory:	
Building addition	$1,251,100
Electrical utilities	43,000
Sewer installation	4,800
Water, gas, and air utilities	1,100
Total, completion of guidance laboratory	1,300,000
Missile engineering building:	
Addition to east end of existing building	285,000
Third floor addition to central portion of existing building	100,000
Equipment	100,000
Total, missile engineering building	485,000
Plant services engineering building	30,000
Administration services building	120,000
Carpenter shop building	170,000
Plant services building	150,000
Total, modernization of existing supporting facilities	2,255,000

Dr. SILVERSTEIN. You will find on the bottom of page 315, its lower half, the new supporting facilities, the vehicle assembly building outlined in detail and adding to a total of $1,383,000; our reports and periodicals building, of $105,000.

The building would be used for bringing together the technical material and editing and reporting it.

The new supporting facilities add to a total of $1,488,000.

The sum of the preceding subtotals that I have given adds to the $9 million estimated cost for the jet propulsion laboratory facilities.

Dr. DRYDEN. May I interrupt, Mr. Chairman, to point out that the land is adjoining the present laboratory. We are not talking about a new site. It is an enlargement of the present site.

Senator STENNIS. Mr. Reporter, insert the remaining part of page 315 at that point.

(The portion of page 315 referred to is as follows:)

New supporting facilities

Vehicle assembly building:	
Building	$963,820
Heating and air conditioning	180,000
Paving	14,000
Outside electrical utilities	85,000
Outside utilities, general	16,990
Design, engineering, and contract administration services	123,190
Total, vehicle assembly building	1,383,000
Reports and periodicals building	105,000
Total, new supporting facilities	1,488,000
Total estimated cost	9,000,000

3. Construction schedule

Total estimated completion time, 14 months.

FUTURE EXPANSION

Senator STENNIS. May I ask you a question for the committee now?

Gentlemen, this is not a large sum of money and, of course, it will be readily granted to meet the need. But is this being spent in such a way now that a year or two from now we may be faced with the fact that this is all too small—that you don't have any expanding room—that you will have to redo the whole thing out in the country or somewhere else?

We have that confronting us now in our military installations. I don't say that critically; but let's avoid it now, if you have any prospect of any future development of that kind.

What is your answer on that?

Dr. SILVERSTEIN. You will find—and in a few minutes I will cover a facility of the type you describe—advanced facility for work on rockets of larger size and using fuels that are too hazardous to use in this area.

The support for these facilities, however, is independent of those needs.

At the laboratory now we have some 2,300 people who are working in the environs of this laboratory. This equipment provides the basic research support which these people—who are living in this area and

who need the associated work of the people alongside of that to work in an integrated fashion—need to do this job.

The new facilities that will be located at a remote site will require a staff which will not require the intimate association with the JPL staff. That is an integrated staff here now that has been working together for years and doing fine work. To break them up to do the small work which can be done on this site would not be in the best interests of carrying forward the work most rapidly.

Dr. DRYDEN. I think the answer to your question, Mr. Chairman, is that we do not see any major expansion of the work at this site. There will be discussed in a later item in the 1959 supplemental and also in 1960, the provision of a remote site where larger rockets and more dangerous substances can be used.

Senator STENNIS. You have to remember, you know, that this agency was created in part to prevent duplications and to insure coordination. We don't want to have to create a new agency in a few years to coordinate you with someone else. You are the frontrunners here now, and we want to keep you in front; but I know it is quite a problem.

I want to raise that issue here sharply and see just what your answer is. We don't know ourselves; but you do know.

All right. Proceed, Dr. Silverstein.

TRACKING FACILITIES

Dr. SILVERSTEIN. The next item I will present is on page 316, entitled "Tracking facilities."

For these facilities funds are requested in the amount of $12,050,000 in fiscal 1959 supplemental.

The funds requested in this project are required to provide the basic tracking, data acquisition, and communications capability that is essential for instrumentation coverage of satellites and space vehicles to be flown during the next 12 to 18 months. New tracking sites are to be established and some improvement will be made to existing equipment. For these purposes three general classes of equipment will be required as follows:

Extension and improvement of earth satellite electronic tracking network——

Senator STENNIS. Would you like to put these in the record now and then make your explanatory comment, or would you rather read it?

I think we can save some time if you give an explanation.

Dr. SILVERSTEIN. Then we find on page 318, for extension and improvement of the satellite electronic tracking stations, the sum of $3,300,000; equipment and facilities for four new stations, modifications and improvement of existing electronic tracking stations, digital read-out equipment, and additional antenna arrays form the basis for this amount.

The second item is facilities for space probe tracking network on page 319 in the amount of $3,500,000. The items that form this are utilities and preparation of the site for these space-probe systems of $1,900,000; two 85-foot diameter antenna systems, $950,000; radio receiving equipment, $460,000; and two antenna servo control systems, $190,000.

Senator STENNIS. For the committee, may I interrupt you there.

There has been quite a bit said about the additional demands for this tracking facility. Maybe that is developing faster than you at one time thought it would. There is a question of duplication; so, my first question is this:

Are you certain now this is enough for your planning for tracking in the supplemental bill?

Dr. SILVERSTEIN. As we are now planning the items, our program is laid out so that this will take care of our immediate needs. We have laid out a plan of development ahead, and that is what is required immediately for carrying the program on.

Senator STENNIS. This, then, will tie in with your 1960 budget?

Dr. SILVERSTEIN. Yes, sir.

You will find in my 1960 presentation more money included for tracking.

Senator STENNIS. And you are not getting into a system here that that is a duplication of anything that is already built—or any process of construction of the services or any other agency—that you could possibly use?

Dr. SILVERSTEIN. I think Dr. Glennan mentioned briefly yesterday that we had gotten together with the Department of Defense and had worked up a national program of tracking of research and development, and this is a part of that plan.

Senator STENNIS. Senator Cannon, do you have a question?

Senator CANNON. Yes, sir.

On page 318, I am concerned about this item for the rework of stations to change frequency, 12 stations at $60,000 each.

Does that indicate that you now have found that you have got to change the frequencies of stations you already had in existence?

Dr. SILVERSTEIN. The frequencies that we are using now are 108 megacycles, which are frequencies established for the IGY.

The current Minitrack stations were established during IGY. This frequency is not a frequency that we will use permanently. The assigned frequency for the purpose of tracking will be more nearly in the range of 240 megacycles.

Dr. DRYDEN. I think we should make clear that this is a matter which is handled by the mechanism for assigning radio frequencies for all purposes.

IGY got a temporary assignment good for the 1½ years. Now, in the assignment of the frequencies broadly they have selected for space communication, space tracking, this new frequency.

Senator CANNON. Is there any likelihood that you will be back next year for an additional request to change the frequencies again, or is this a permanent assignment that will solve the problem once and for all?

Mr. WYATT. We are requesting a permanent assignment of a new frequency.

Dr. DRYDEN. It is as permanent as any frequency that the FCC gives. It is in the same category as an FCC frequency assignment.

Senator STENNIS. May I insert at this point an agreement between NASA and the Department of Defense with reference to this global tracking?

It is dated January 10, 1959, and signed by Dr. Glennan and by Secretary McElroy.

(The material referred to follows:)

AGREEMENT BETWEEN NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND DEPARTMENT OF DEFENSE ON GLOBAL TRACKING, DATA ACQUISITION, COMMUNICATIONS, AND DATA CENTERS FOR SPACE FLIGHT

1. The separate requirements of NASA and the Department of Defense for space tracking and data acquisition are recognized. The NASA requirements are primarily for research and development flights and the DOD requirements are primarily for research, operational flights, and intelligence support.

2. Immediate and vigorous action is required in both agencies to implement the agreed-on national program.

3. It is agreed that the following actions be started in the current year:

(*a*) Provide tracking and data acquisition stations for deep space probes at Woomera, Australia, and South Africa using one of the existing 85-foot dishes. This will complete a three-station net including the existing NASA Goldstone facility for 24-hour coverage of deep space flights. These stations will be operated by NASA. High capacity data acquisition equipment will be required at these sites by the Department of Defense in the near future. These stations will provide for DOD requirements until the load increases so that parallel DOD equipment is required.

(*b*) Provide one of the existing 85-foot dishes in Spain and a secondary acquisition antenna with high capacity in Japan. These stations will be operated by the Department of Defense. These stations will provide for NASA requirements until the load increases so that parallel NASA equipment is required.

(*c*) Provide facilities required for project MERCURY, including those for injection, tracking, data acquisition, and reentry command. The NASA will provide and operate these facilities.

(*d*) Add four stations to the Minitrack network and modernize remaining stations to provide coverage for polar flights. NASA will provide and operate these stations.

4. The need is recognized for two closely cooperating data reception and analysis centers, one operated by NASA as a continuation and expansion of the Vanguard center and one operated by the Department of Defense under Spacetrack management at the Cambridge Research Center. These two centers will exchange data freely and provide mutual support for the national program.

5. The worldwide communications networks now in existence shall be shared equally by DOD and NASA.

6. A technical committee with representation from NASA and DOD shall maintain a continuing study and monitoring of the global tracking, data acquisition, and communications problems and periodically report their findings for action to the Secretary of Defense and the Administrator of NASA.

Senator STENNIS. Signed "Neil H. McElroy, Secretary of Defense" and "T. Keith Glennan, Administrator, NASA."

I would also like to put in the record at this point a supplemental statement on tracking facilities prepared by NASA at the request of the committee:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TRACKING FACILITIES, FISCAL YEAR 1959 SUPPLEMENTAL ESTIMATES

The NASA fiscal year 1959 supplemental budget request of $12,050,000 for the establishment of nine new tracking sites consists of 4 Minitrack stations in Alaska, United States, Newfoundland, and Canada; 2 deep-space probe tracking stations in Australia and South Africa; and 3 stations in Hawaii, Texas, and Bermuda for tracking and control of the manned satellite.

The exact location of the stations has not yet been determined pending the result of site surveys, some of which are now underway. The particular area in Texas cannot be precisely located pending further study of the exact flight paths of the manned satellite.

The area required for each of the new tracking stations will be 30 to 50 acres for the initial installation, plus an additional 30 to 50 acres to allow for possible future expansion. Some use restrictions must also be placed on the area surrounding the sites in order to avoid construction of industrial facilities which would interfere with the proper operation of sensitive radio tracking equipment. The size of this restricted area will depend upon the local terrain but will extend an estimated one- or two-mile radius around the station.

It is expected that the new stations will be located either on leased land or on existing U.S. property so that new land purchases will not be involved.

It is estimated that 20 to 25 persons will be required to manage and operate each station.

Senator STENNIS. You may proceed, Doctor.

Dr. SILVERSTEIN. I mention next the item, equipment for support of manned space vehicles, on page 319 in the amount of $5,250,000.

This is the long-leadtime equipment, radar equipment, required for the insertion tracking of the vehicle, for the initial reentry tracking and midcourse tracking for the capsule.

It is very essential that we know at every point in the trajectory where this capsule is so that we can press a button at the right time to initiate retrorocket action and recover.

These items add up to the $12,050,000 that I mentioned earlier.

Senator STENNIS. All right.

Now, with reference to these pages before us, 316 through 319, these are the items and the estimated cost, your asking money, for these items for the reasons you have given.

Dr. SILVERSTEIN. Yes, sir.

Senator STENNIS. Do you vouch for these estimates? Do you think they are fairly accurate?

Dr. SILVERSTEIN. I think these are good engineering estimates, sir.

Senator STENNIS. Who is your construction agent for laboratories or any buildings which you may build?

Dr. SILVERSTEIN. We follow the normal course and practice of doing initial designing, calling in architect-engineering groups to carry along the design further and then of letting bids for construction.

Senator STENNIS. You let the bids yourself or do you have the U.S. Engineers or someone else represent you?

Dr. SILVERSTEIN. We let the bids ourselves, sir.

Senator STENNIS. For the committee, I would like to insert the pages 316 through 319 in the record at this point.

They are the items that I referred to in my questions of Dr. Silverstein.

(Pages 316 through 319 are as follows:)

VARIOUS LOCATIONS, FISCAL YEAR 1959 SUPPLEMENTAL ESTIMATES, TRACKING FACILITIES

1. DESCRIPTION AND JUSTIFICATION

These funds requested in this project are required to provide the basic tracking, data acquisition, and communications capability that is essential for instrumentation coverage of satellites and space vehicles to be flown during the next 12 to 18 months. New tracking sites are to be established and some improvement will be made to existing equipment. For these purposes three general classes of equipment will be required as follows:

Extension and improvement of earth satellite electronic tracking network

Experience gained during the initial operation of the minitrack electronic tracking stations in the IGY tracking satellite program has established the need for improving and augmenting the existing equipment to provide more reliable handling and transmission of tracking data and to provide increased capability for tracking of satellites in high inclination orbits. To accomplish these objectives it is planned to establish four new electronic tracking stations in Alaska, the United States, Newfoundland, and Europe, and to install additional and improved equipment at some of the existing minitrack stations.

The equipment to be installed at each of the new stations will include antenna arrays, telemetry receiving equipment, communications equipment, command transmitters, and calibration equipment.

The improvements to the existing stations will include addition of real-time digital data read-out equipment, and additional antenna arrays for coverage of satellites in high inclination orbits. It is also necessary to shift the operation of all stations to a higher radio frequency since the 108 megacycle frequency presently used for tracking U.S. satellites is a temporary assignment. To make this frequency change will require reworking of all minitrack radio receiving equipment and antenna arrays.

Space probe tracking network

The tracking and reception of telemetry data from space probes will require the provision of special high-gain, low-noise receiving systems at several points on the earth's surface. It is accordingly planned to provide a network of stations to support flight experiments of this type. One of these stations has been built at Goldstone, Calif. Funds are requested in this project to provide for the establishment of two additional stations, one in Australia and the other in South Africa. Each station will include large parabolic-antenna equipment to pick up the low-level signals, sensitive radio receiving equipment, and electronic-hydraulic servo system for controlling the antenna. The amount requested will provide for initial site preparation and for basic equipment procurement.

Equipment for support of manned space vehicles

Insertion tracking and guidance system.—Detailed studies of the problems of recovering earth satellites, particularly manned systems, has established the desirability of northeast launchings from the Atlantic missile range site at Cape Canaveral with recoveries on the second and third orbits down the existing Atlantic missile range complex. Such operations will require the installation of precision radar acquisition, tracking, communication, and associated systems at Bermuda to provide accurate trajectory information on the satellite after booster cutoff to establish that the satellite is in the desired orbit and to initiate abort action if unsatisfactory conditions exist. This station will also provide down-range data acquisition capability for long-range missiles and satellites launched from the NASA Station at Wallops Island, Va.

The funds requested here will permit initiation of the procurement of the basic precision radar system which requires a long leadtime for delivery.

Initial reentry tracking and control system.—Recovery of a manned satellite system on the second and third orbit down the Atlantic missile range will require precision tracking of the satellite during the reentry phase. It is, therefore, proposed to provide precision radar acquisition, tracking, communication, and associated systems at Hawaii to provide initial impact point prediction during the first phase of satellite reentry. This station will also provide a capability for emergency command control of retrorocket firing in the satellite in the event of malfunctioning of the preset timer systems.

The funds requested here will permit initiation of the procurement of the basic precision radar system which requires a long leadtime for delivery.

Midcourse reentry and landing tracking system.—In order to provide adequate precision tracking of a reentering satellite between the areas in Western and Eastern United States now covered by existing range systems it will be necessary to provide precision radar acquisition, tracking, communications, and associated systems at a location in southern Texas. This station will be equipped for precision tracking of satellites launched northeast from Cape Canaveral on the first, second, and third orbits. This will also provide refinement of the impact point prediction for satellite recovery on the second or third orbits down the Atlantic missile range. This station will also provide the critical tracking capability during the final stages of reentry and landing if land recovery of the satellite on the Texas plains during the first, second, or third orbit is required.

The funds requested here will permit initiation of the procurement of the basic precision radar system which requires a long leadtime for delivery.

2. Cost estimate

Extension and improvement of satellite electronic tracking stations	$3,300,000
Equipment and facilities for 4 new stations, at $531,000	2,124,000
Antenna arrays	110,000
Electronic equipment	346,000
Site preparation and utilities	75,000
Modification and improvement of existing electronic tracking stations	1,176,000
Rework of station to change frequency: 12 stations, at $60,000	720,000
Digital read-out equipment: 6 stations, at $26,000	156,000
Additional antenna arrays: 6 stations, at $50,000	300,000
Facilities for space probe tracking network	3,500,000
Initial site preparation, roads, utilities, housing (2 stations)	1,900,000
85-foot diameter antenna systems (2)	950,000
Radio receiving equipment (2)	460,000
Antenna servo control systems (2)	190,000
Equipment for support of manned space vehicles	5,250,000
Precision radar system for insertion tracking and guidance	1,750,000
Precision radar system for initial reentry tracking and control	1,750,000
Precision radar system for midcourse and landing tracking	1,750,000
Total estimated cost	12,050,000

Senator STENNIS. All right, Doctor; what do you have next?

PROPULSION DEVELOPMENT FACILITIES

Dr. SILVERSTEIN. The next item is on page 312, propulsion development facilities.

Here we have facilities in the amount of $3,200,000 shown on page 321 for thrust stand modification, gas generator facility, and a turbopump facility, adding up to this total of $3,200,000.

I explain and justify this item for development of the million to a million-and-a-half-pound rocket, described in my booster presentation, now in progress.

We find it necessary to provide new facilities to enable this rocket to be tested on the ground previous to flight. This rocket, of course, is some 10 times larger than any rocket that we now have in flight. It has a pump on it that is five times larger than any pump previously built and it requires 65,000 to 75,000 horsepower to drive the pump.

These pumps provide for a gas generator system as an energy source to drive the turbine that is connected to the pump.

It provides for a stand on which to test the pump.

This pump will pump both the liquid oxygen and the kerosene that is used to fuel the rocket.

This piece of machinery is larger than any of our current jet engines, and the technical development of the pump and its turbine must be brought to a high state of reliability before we carry it to flight. We achieve this with the ground test facilities.

There is also an item here for some $750,000 for modifications to existing test stands that are required for the thrust-chamber development.

Again we find this thrust chamber, being so much larger than any previous thrust chamber, needs to have special construction in order to hold it when it is fired.

Senator STENNIS. May I ask a question there. This is general and for the committee:

You have this additional requirement now, and you are talking in terms of the liquid fuels altogether.

There are two questions in my mind: Will this be used by you exclusively or will it be open to any other development that may be carried on by any of the services or any other agency of the Government should they get into this field?

Dr. SILVERSTEIN. We are doing this project and linking it very closely with the Air Force who may have a use for it perhaps in the future. We are keeping them thoroughly informed.

In fact, we have in our office a representative of the Air Force working on this project, so that they can be intimately acquainted.

Senator STENNIS. I know, but have you really tied it in now and agreed on something, or will the Air Force come here later in this session or in the next session and say they must have one?

That is what we want to get to right now.

It seems to me that this is a good time for you to nail down something so we will know and select a site that is suitable for all purposes.

Dr. SILVERSTEIN. The site we have here, of course, this $750,000 for the thrust stand, will be only a part of the facilities required for the eventual development of this rocket. This is only for the development of the thrust chamber.

Senator STENNIS. I know.

Dr. SILVERSTEIN. The facilities for the turbogenerator, of course, are singular and will be used jointly in all major engine developments.

Senator STENNIS. Do we understand now concerning this project—not only this initial installation you are going to start out with but this project as a whole—is it contemplated and has there been an understanding that this will be used by all agencies that may need it?

Dr. SILVERSTEIN. Yes, sir.

Senator STENNIS. Whether it is the Air Force or whoever it may be?

Dr. SILVERSTEIN. That is our understanding.

Senator STENNIS. Is that correct?

Dr. SILVERSTEIN. Yes, sir. We are well coordinated.

Senator STENNIS. What is the estimated total cost of all of it? Do you have in mind a figure?

Dr. SILVERSTEIN. The firm figure we have now for development of the engine and the first engines to run through performance tests is in the order of $110 million for the initial phases.

Senator STENNIS. Dr. Dryden?

Dr. DRYDEN. Facilities?

Senator STENNIS. Yes, I was talking about facilities.

Dr. SILVERSTEIN. The facilities in addition to this currently are on the order of $4 million in addition to the ones we have here.

Senator STENNIS. You have $3.2 million here now, and that you will ask for later?

Dr. SILVERSTEIN. Yes.

Senator STENNIS. Where is this located?

Dr. SILVERSTEIN. The $4 million?

Senator STENNIS. This item, this new facility.

Dr. SILVERSTEIN. These new facilities will be partly located at the contractor's plant at Santa Susana, and partly at Edwards Air Force Base at the Air Force Rocket Facility.

Senator STENNIS. How far apart are they?

Dr. SILVERSTEIN. They are separated. They are not joined. They are separated.

Senator STENNIS. You are the gentlemen that know about this. At least I don't have any special knowledge of it. I think we are standing right on the brink here of major decisions with reference to these future operations of plants and facilities.

We are dependent on you to say that these facilities are designed and will be suitable for all the needs that can be anticipated not only by you but by the other services in their related work.

Now, do you feel that you have done that and can answer affirmatively?

Dr. SILVERSTEIN. Yes, sir.

I would say that our whole program in this booster area and in the rocket area is being very closely coordinated with all the services. We have made very special plans to bring them into all of the sessions. We bring people into our groups representing the various services so that they can keep informed not on a gross basis but on a day-by-day basis.

Senator STENNIS. That is very good, but what I am interested in now is: Is this being fixed so that it will be used by the armed services so that a request will not be coming to the Armed Services Committee for a similar setup?

Dr. SILVERSTEIN. The intention is that we will use them jointly.

Senator STENNIS. All right, the intention is that you will use them jointly.

Do you have a formal agreement to that effect?

Dr. SILVERSTEIN. We have an agreement with the Air Force for the use of their facilities now on that basis.

Senator STENNIS. Mr. Lehrer, will you notify the other branches of the services to examine this record to see what they say with reference to the question—if this is suitable for their purposes—and whether they are planning to use these facilities or do they expect to request their own additional facilities?

(The material referred to above is as follows:)

FEBRUARY 23, 1959.

Hon. NEIL MCELROY,
Secretary of the Department of Defense,
The Pentagon, Washington, D.C.

DEAR MR. SECRETARY: As you know, Public Law 85–568, which established the National Aeronautics and Space Administration, contains several provisions designed to eliminate duplication in space activities between NASA and the armed services. I know you will agree that we must take every practicable step to prevent the waste of money and scientific and material resources that would be involved in any such duplication.

This subcommittee has just held 2 days of hearings on S. 1096, a bill to authorize supplemental appropriations to NASA for the fiscal year 1959. The NASA witnesses have testified that there is no present or prospective duplication with any of the armed services with respect to the programs or facilities for which these supplemental appropriations are being requested.

To assure that there is no confusion on this matter, it would be appreciated if you would examine the transcript of the hearings and advise us whether you agree with the statements made by the NASA witnesses.

In the event you do not agree that there is no duplication with NASA with respect to the space activities for which supplemental authorizations are being requested, by the executive branch, we will provide you with an opportunity to testify in detail as to any present or prospective duplication.

Identical letters on this matter have been sent to the Secretaries, of the Army Navy, and Air Force.

Sincerely yours,

JOHN STENNIS,
Chairman, NASA Authorization Subcommittee.

ADVANCED RESEARCH PROJECTS AGENCY,
Washington, D.C., February 25, 1959.

Hon. JOHN STENNIS,
Chairman, NASA Authorization Subcommittee,
U.S. Senate.

DEAR MR. CHAIRMAN: The Secretary of Defense has asked me to reply to your letter of February 23, 1959, requesting that we advise you as to our agreement with certain statements made by NASA witnesses on S. 1096, a bill to authorize supplemental appropriations to NASA for fiscal year 1959. The specific statements in question involve testimony by NASA witnesses to the effect that there is no present or prospective duplication with any of the armed services with respect to the programs or facilities for which these supplemental appropriations are being requested.

The Advanced Research Projects Agency is generally familiar with the NASA request for $48 million of supplemental funds for fiscal year 1959, and, while we did not actively participate in the preparation of the request, to our knowledge and from a reading of the transcript of the hearings, the funds requested are for work which will not duplicate that of DOD/ARPA. The funds requested for tracking facilities will complement the DOD/ARPA effort to conduct a fully coordinated program.

It should be noted, however, that this is a supplemental request of the NASA for their space programs and for only their portion of those programs administered jointly by the NASA and the DOD. The Defense portions of these joint programs and the Defense military space program have been and are being presented separately in the DOD budget requests.

Sincerely yours,

(Signed) LAWRENCE P. GISE,
(For ROY W. JOHNSON, Director).

FEBRUARY 26, 1959.

Hon. JOHN STENNIS,
Chairman, NASA Authorizations Subcommittee,
Senate Committee on Aeronautics and Space Sciences.

DEAR MR. CHAIRMAN: In response to your request of February 23 1959, the Department of the Army has reviewed the transcript of testimony by NASA witnesses before the NASA Authorizations Subcommittee of the Senate Committee on Aeronautics and Space Sciences on February 19–20, 1959, to determine if the testimony indicates any present or prospective duplication insofar as the Army is concerned with respect to the programs or facilities for which the supplemental appropriations in the amount of $48,354,000 are being requested.

Based on a reading of the transcript of the hearings, the Department of the Army considers that there is no present or prospective duplication between the NASA and the Army with respect to the program or facilities for which supplemental appropriations are being requested, to wit—salaries, $3,354,000; project Mercury, $20,750,000; and the facilities construction including JPL, $9 million; tracking, $12,050,000; and propulsion development, $3,300,000.

On page 199 of the transcript you posed two questions on the suitability and planned use of the propulsion development test facilities discussed by Dr. Silverstein. As you know, the Army Ordnance Missile Command is developing, under ARPA direction and with ARPA funds, a 1½ million pound thrust booster based on a cluster of available rocket engines. Certain facilities are available at Huntsville, Ala., for the development and test of this booster. Although the NASA development of a million pound thrust chamber is in a different time frame by at least 3 years, it is a logical and desirable follow-on program. The NASA

single chamber engine may very possibly be used in a cluster to provide for a multimillion pound thrust space vehicle booster. Due to physical characteristics of components, however, development and test facilities required for one program cannot be used for similar testing in the other program. For this reason, no Army requirement is foreseen at this time for use of the NASA requested facilities. The Army, however, considers these facilities necessary for the successful execution of the NASA program.

Sincerely,

WILBER M. BRUCKER,
Secretary of the Army.

DEPARTMENT OF THE NAVY,
OFFICE OF THE SECRETARY,
Washington, D.C., February 25, 1959.

Hon. JOHN STENNIS,
Chairman, NASA Authorization Subcommittee,
Committee on Aeronautical and Space Sciences,
U.S. Senate, Washington, D.C.

MY DEAR MR. CHAIRMAN: This is in reply to your letter of February 23, 1959, concerning testimony of NASA witnesses before your subcommittee on 19 and 20 February 1959.

I have examined the transcript of the hearings and am in agreement with the statements made by the NASA witnesses.

Sincerely yours,

THOMAS S. GATES, Jr.,
Secretary of the Navy.

DEPARTMENT OF THE AIR FORCE,
OFFICE OF THE SECRETARY,
Washington, D.C., February 26, 1959.

Hon. JOHN STENNIS,
Chairman, NASA Authorization Subcommittee,
Committee on Aeronautical and Space Sciences, U.S. Senate.

DEAR MR. CHAIRMAN: The Secretary of the Air Force has asked me to reply to your letter of 23 February 1959 concerning the recent hearings of your subcommittee on S. 1096, a bill to authorize supplemental appropriations to NASA for fiscal year 1959.

The transcripts for the 2 days of hearings on this subject have now been reviewed as carefully as time would permit. Based upon a review of the material available from this source, the Air Force did not find any evidence of duplication resulting from the supplemental appropriations to NASA.

The opportunity offered by your subcommittee to review this matter is appreciated and I can assure you that we in the Air Force will continue to do everything that we can to eliminate any possible duplication in the national space program.

Sincerely yours,

LYLE S. GARLOCK,
Assistant Secretary of the Air Force.

Senator STENNIS. All right, do you have something further before we have questions?

Dr. SILVERSTEIN. I can mention the facilities for 1960, if you would care to hear them.

Senator STENNIS. Members of the committee, I didn't have in mind that we would go into the line items for 1960 unless it might be necessary to explain some item in the supplemental. That will be a long process to cover all that for 1960——

Dr. DRYDEN. That's right.

Senator STENNIS. I think that would have to be set for several days of hearings on that.

I would like for other members of the committee to have a chance to ask some questions now if we might.

Senator Smith, may I call on you?
Senator SMITH. Yes.

RELATIONSHIP WITH OTHER FACILITIES

I want to go into anticipation of the services and other agencies Mr. Chairman.

Your justification, Doctor, indicates that you are requesting $3,200,000 for an adaptation of an addition to facilities to be used by Rocketdyne Division of North American Aviation Corp. on the 1-million-pound-thrust rocket engine.

Would you explain the relationship between these facilities and those already provided by the Air Force and the contractor?

Dr. SILVERSTEIN. Yes, indeed.

The facilities at the plant that we will use are facilities that are owned by the Air Force and are located at the contractor's plant.

We have obtained permission from the Air Force by agreement to use these facilities for the development of the larger engine, and these have to be modified, however, to accommodate the larger-sized engines as compared to the sizes of engines they have been testing now.

As I mentioned earlier, these are some 10 times larger than the engines that are being used in our current ICBM's.

Senator SMITH. In the cases where you propose to adapt facilities, will NASA or will the Air Force own or control them?

Dr. SILVERSTEIN. They are Air Force facilities and we will use them.

Senator SMITH. They do belong to the Air Force.

Dr. SILVERSTEIN. Yes, indeed.

Senator SMITH. It is part of their inventory.

Dr. SILVERSTEIN. Yes.

Senator SMITH. How do you draw the line between what NASA finances, what the Air Force finances, and what the contractor finances?

Dr. SILVERSTEIN. The financing of the test that is made within the facility would be by NASA on contract with the Rocketdyne Co.

Senator SMITH. And could the facilities be operated by any other contractor?

Dr. SILVERSTEIN. They may be.

Senator SMITH. By special arrangement?

Dr. SILVERSTEIN. By special arrangement; yes.

Senator SMITH. Not without the approval of NASA?

Dr. SILVERSTEIN. Without Air Force approval.

Senator SMITH. Thank you, Mr. Chairman.

Senator STENNIS. Thank you, Senator Smith.

Senator DODD?

Senator DODD. I don't have any questions at this time.

Senator STENNIS. Senator Martin?

TOTAL CONSTRUCTION EQUIPMENT

Senator MARTIN. I have checked over the sections that you have covered here at this time on construction equipment.

The grand total outlined as you have presented it here on construction equipment totals the amount in the bill S. 1096 for that purpose?

Dr. DRYDEN. Yes.

Senator MARTIN. $24,250,000?

Dr. SILVERSTEIN. Yes.

Senator WILEY, How much?

Senator MARTIN. The grand total in construction equipment comes to $24,250,000. That is the amount covered in the section that was just covered.

I have the correct amount, do I?

Dr. SILVERSTEIN. That is correct.

Senator MARTIN. I have no questions about the sufficiency of it or the insufficiency of it. I take your word for that.

Senator STENNIS. Senator Cannon.

SANTA SUSANNA FACILITY

Senator CANNON. Thank you, Mr. Chairman.

You indicated that there was to be some expansion of facilities at Santa Susana; is that correct—on that project?

Dr. SILVERSTEIN. Yes, sir.

Senator CANNON. Isn't it correct that the Santa Susanna facility is being used to about maximum capacity because of the encroaching areas such as you are trying to eliminate in this JPL project?

Dr. SILVERSTEIN. I really cannot answer that.

There are spaces and this project has been designed to date, so there is a place to put this within the facility.

Senator CANNON. Do you anticipate that if you increase the facility there, you wouldn't be back again in the immediate or foreseeable future to request removal of the entire project to some other location so that you can carry on greater thrust tests?

Dr. SILVERSTEIN. I mentioned earlier that there were additional facilities and that the final tests will be at Edwards and there will be facilities at Edwards.

The facilities asked for here take care only of the thrust chamber and of the pump and turbine system.

The actual engine tests will require facilities at Edwards, the whole pump and tanks above it.

Senator CANNON. Do you anticipate tests in the foreseeable future at Santa Susana that will encounter difficulties because of encroaching areas—encroaching residential areas—around that project?

Dr. SILVERSTEIN. I don't predict it.

Senator CANNON. Thank you. Nothing further.

Senator STENNIS. Senator Wiley.

Senator WILEY. I have a bill here which I suppose is the basis of this hearing.

Senator STENNIS. That is correct, Senator.

Senator WILEY. It is $48,354,000 for the National Aeronautics and Space Administration. Then there is the additional amount for salaries, $3.354 million——

Dr. DRYDEN. That is the breakdown of the $48 million that you are reading now.

Senator WILEY. Are you sure of that?

Dr. DRYDEN. Yes, sir.

Senator WILEY. All right, that is a breakdown.

Then there is the additional amount for research and development, $20,750,000, and then the amount that was just asked for here, $24,250,000—then the $9 million for the jet propulsion laboratory and then the various locations, global range tracking and so forth, $15,250,000.

That all adds up together with the $24,250,000.

Dr. DRYDEN. It adds to the total amount of $48 million.

What you are reading is the separate items that add to the total of $48,354,000.

Senator WILEY. I have got that straight in my mind.

Now, the next question is in arriving at these amounts—I presume that you have had expert people with you who see that these figures are correct.

Dr. SILVERSTEIN. These are based on very sound engineering studies. The tracking facilities, the cost of these are quite well founded. We have in fact based them upon the costs of existing facilities.

Senator WILEY. That is all.

Senator DODD. Could I ask another question?

Senator STENNIS. Certainly, Senator Dodd.

"CAMAL" PROJECT

Senator DODD. Are you familiar with a project called the "Camal" project?

Dr. DRYDEN. Yes, sir.

Senator DODD. It occurred to me in listening to the questioning—as I understand it—that project cost a lot of money and then was shut down.

Dr. DRYDEN. That is a nuclear facility, Senator.

Senator DODD. Yes.

Dr. DRYDEN. It has no relation to this type of facility we are talking about.

Senator DODD. I understand that.

The point that is in my mind is this: We spent a lot of money to put that facility up. It wasn't up very long, and I don't think it ever really got under operation before it was practically abandoned.

You wouldn't run into anything like that, I hope.

Dr. DRYDEN. Not unless the space program is abandoned.

There was a cutback in the nuclear program, I believe.

Senator DODD. I don't know what caused it, but I suppose that is the kind of thing we are trying to avoid.

Senator STENNIS. That's correct.

PROGRAM DUPLICATION

Members of the subcommittee, I am emphasizing this matter because right here at this table I saw all these missile programs grow up with duplications including appropriations for money, scientists, and talent—and I feel guilty to an extent for being a party to it. It was all new and no one knew what we were doing so far as the subject matter was concerned.

There was certainly no willfulness on the part of any of the services. They were doing what they thought they should do, of course; nevertheless, the result was bad. It was very expensive—and this is a

new chance now to avoid the same error. We need the utmost cooperation of you gentlemen, and I think we will have it; but I think we ought to call in all who may be involved in similar work and let them state their position in the record—then everyone will have had his day in court and everyone will be bound then by the decision.

May I ask one other question, too.

COSTS OF CONSTRUCTION

The U.S. engineers do all the construction work for the Army and for the Air Force—then we have the Bureau of Yards and Docks with their engineers, architects, facilities, and their experience. I haven't conferred with you about this, but why couldn't NASA as an agency of the Government use those gentlemen or some of them, with their know-how and ability, rather than having to go out and build up your own organization somewhere else?

Dr. DRYDEN. We are not building up any additional construction group.

In the NASA experience with which you are probably familiar, we have, I think, an extremely creditable record on the amount that we have gotten for the dollars spent on facilities. I think you, sir, have visited some of them and are perhaps familiar with them. There may be certain instances, for example, in construction overseas where it will be advantageous to use the Corps of Engineers, the Bureau of Yards and Docks. In general, most of our facilities have been extremely specialized where we have an extremely competent staff already on hand and through commercial contractors we have been able to proceed at a very reasonable cost, we think.

Senator STENNIS. I take at great value, Doctor, whatever you testify to—I have heard your testimony for a long time—but the substance of what you say is that you haven't felt the need for it yet.

Dr. DRYDEN. Not yet.

Senator STENNIS. Have you been able to get a good job done and do you think there is a low unit cost, too?

Dr. DRYDEN. Every time you put another link in the chain, we find it has a tendency to increase the costs; so, if we can avoid going through still another organization, we think we can keep things down at a lower cost.

Senator STENNIS. If you get into a large construction program you may have to yield your position on that. Do you think you will be driven to getting some other aid?

Dr. DRYDEN. I should make clear we have used the services of industrial groups. We do not do any detailed designing, for example.

Senator STENNIS. You are not building up a corps of your own?

Dr. DRYDEN. We do not have a large design group as such. We have people who place contracts who inspect, who guide the architect-engineer firms that we employ and so on.

Senator STENNIS. I hope that the staff member here who has been assigned to our subcommittee will have a chance to familiarize himself with your construction processes and perhaps go out on one of these projects.

Senator Wiley, do you have a question?

Senator WILEY. Yes.

RUSSIAN ROCKET PROGRESS

First I want to say that I have listened with profit to the explanation that has been given here and these young men seem to be dedicated men. But I am anxious about that matter of thrust.

Have you given consideration, or have you any idea of how the Russians got the larger thrust, and whether they are using a new form of energy?

Dr. DRYDEN. No, sir. We think we understand how this came about.

The Russians developed a warhead which was heavy. To put this warhead across the distances they wanted, they had to have larger rockets. We had, as you may recall, developments in warhead which greatly reduced the size and weight.

Therefore, we were able and have been able to do the same job with smaller rockets. So the Russians went along the way they had to go to put their heavier warheads a greater distance.

Now, as a byproduct, then, they have this larger thrust available for space missions.

As far as we know, the general nature of their rockets is the same as ours. They are just bigger.

FUTURE ENERGY RESEARCH

Senator WILEY. Are you foreclosing your mind from seeking to discover, in this age of discovery, a new force or a new energy? We talk about atomic energy; we talk about this and that. Are you still exploring to see whether you have missed the boat on anything?

Dr. DRYDEN. No. We have mentioned the use of high-energy fuels, higher energy fuels, which is one way of getting more thrust out of the same size rocket size. We have mentioned nuclear energy, which will come along in 5 to 10 years in these areas.

We have an eye on fusion. We haven't accomplished fusion yet in any form. Certainly, if we get fusion as a fact, we are interested in the possible application to space. But this is in the future. We have been talking to you about things which can be done in the next 5 years, 5 to 10 years, earlier than that in some cases, beginning 2 years from now.

So we are not neglecting these other things. We have research work on so-called ion propulsion, which gives you an engine which has perhaps 1/100th the fuel consumption of an existing engine.

Unfortunately, it is very heavy and it gives very low thrust; so, it is not very useful near the earth where you have the gravitational field, but extremely useful in space missions.

These things are at the moment in a research stage and are not ready to go out and get some engine manufacturer to build an engine.

But I do not know of any source of energy that is being overlooked in the studies of propulsion for space.

Dr. SILVERSTEIN. Mr. Chairman, I might say for those who might be interested in following up these developments, if you visit our laboratories, we will be glad to show you these ion systems and plasma systems under study and in operation.

Senator STENNIS. Thank you very much.

Dr. DRYDEN. May I correct the record?

I have been informed that we did use the Army Engineers for the project at Fort Churchill.

Senator STENNIS. Thank you.

Members of the committee, I am going to call on Mr. Lehrer now, a member of our staff, who has been assigned to our subcommittee.

He prepared, here, some questions that I think are very relevant.

This is the logical place, Mr. Lehrer. Will you ask these questions?

JET PROPULSION LABORATORY

Mr. LEHRER. Thank you, Mr. Chairman.

I believe the record would benefit from clarifying a number of points with respect to the exact status of the Jet Propulsion Laboratory.

Dr. Dryden, will you tell us, does the California Institute of Technology have any property rights in the Jet Propulsion Laboratory?

Dr. DRYDEN. None whatever, sir. It is all Government-owned.

Mr. LEHRER. Then exactly what is the relationship between the Laboratory, the California Institute of Technology, ARPA, and NASA?

For example, are the personnel at Jet Propulsion Laboratory included in the 8,961 figure quoted by Dr. Glennan?

Dr. DRYDEN. They are not. The Laboratory is organized and managed by the California Institute of Technology. It does not exist as a corporate entity; so that it is run by contract between NASA and the California Institute of Technology just as it has been run for all these years under the contract between the Army and the California Institute of Technology. There has been no change in its status with respect to the Government except that the Government agency which owns the property and operates the contract is now NASA rather than the Army.

This is the only change.

Mr. LEHRER. Are the salaries paid to the scientists and other personnel at JPL comparable to those that you pay the direct employees of NASA?

Dr. DRYDEN. We have made a study, a statistical study, of the salary scale at JPL as compared to governmental salaries as an incident to examining and negotiating the basis for contracts, and generally speaking they are comparable. There are perhaps a few of the salaries at the upper end that are slightly different, but generally speaking the salary scales are proper.

JPL AND BELTSVILLE SPACE CENTER

Mr. LEHRER. What is the relationship between the work being done at JPL and the work to be done at the new Space Projects Center at Beltsville, Md.?

Dr. DRYDEN. The competence of JPL is primarily in the field of electronics, guidance, control, communications, solid propellant rockets, with some smaller amount of work in materials and aerodynamics.

The Beltsville center is the center for space science.

The scientists who are planning and working on the payloads that Dr. Newell was talking about for making measurements with the use of satellites—to put it another way, JPL will be concerned with the vehicles. The Beltsville Space Center will be concerned with the

scientific payloads, the data analysis that comes back by telemetering from the satellites. This is the distinction.

Mr. LEHRER. And can JPL, in your opinion, operate effectively separated from the Army Ballistic Missile Agency at Huntsville?

Dr. DRYDEN. Yes. They were in the capacity of a supporting agency. In fact, we think that the general supporting research at the laboratory in the fields that I have mentioned, will also support the work of the Army, and just as the work of the NASA research centers support the work through the Department of Defense.

In addition, we will use JPL to help us in the technical monitoring of some of the specific contracts, vehicle developments.

Mr. LEHRER. Thank you, Dr. Dryden.

Senator STENNIS. All right, are you ready to move into the next phase?

NUCLEAR ENGINE PROGRAM

Senator CANNON. If I may just ask one further question.

Doctor, there has been an inference here throughout the whole program that you have present that in the future, at some time in the future, the nuclear engine would no doubt replace the engines that you are working on now, or would at least give you a greater thrust for the weight involved.

Dr. DRYDEN. That is true.

Senator CANNON. Now my inquiry is directed toward the Rover project and the nuclear program in general—to ask whether or not a speedup at this stage of the process in the Rover type or nuclear project would in effect eliminate any of these costs in the development of the big cluster propellants at this time?

Dr. DRYDEN. I think not. It would perhaps be better for us to arrange to have one of the Rover people come in if you wish to talk about that. We are depending on them for estimates of the support which we furnish.

The direct nuclear appropriation is in the AEC appropriations. In other words, they are doing the nuclear reactor part. We are doing the support of the rest of the vehicle, and our estimates on that so far have been essentially those made by the Rover project people.

Senator CANNON. That brings to mind the questioning that Senator Wiley raised a little while ago. Maybe we have got some duplication or maybe we have got something here that is going to have to be done away with in the not too distant future, because of the progress that comes along and I am quite concerned.

Dr. DRYDEN. This is, of course, a matter of technical judgment. It is going to be quite a problem to use nuclear rockets in the first stage, taking off from the surface of the earth, because of the radioactive-hazard problem, the fallout problem.

The earliest application, we feel, will be in the upper stages where you turn your nuclear rocket on after it is out in space and will not affect anyone down on earth. We believe that the first booster stages for a very long time are going to be chemical, for a great many reasons. Now in the distant future this may change. We are told by the AEC people that the development of nuclear rockets is still in an early research and development stage. The estimates as I recall before the Space Committe given by the witnesses from the AEC were that certainly we would not have any such engine for some period of the

order of 5 to 10 years, that this could not be hurried up very much, because it is dependent on materials development that will withstand the high temperatures and the flow of hydrogen through it.

But I think you could get a better feel for this by witnesses from the laboratory that is actually carrying on the work.

Senator CANNON. Mr. Chairman, I think it might be well, if the suggestion is in order, that sometime we hear from the people in that program, because I would certainly hate to see us go ahead and spend millions or billions of dollars on this engine development program and then find out that about the time we get it developed, we have a nuclear engine that will supplant it and will have made all this useless.

Dr. DRYDEN. Just another further statement: The nuclear engine in the opinion of most of the experts will come in only for the very largest payloads and for the very distant space missions where you have to have very high initial velocity.

Senator STENNIS. If you would suggest exactly the gentlemen that you think we should call, I would like for you to inform Senator Cannon.

Did you have that in mind, Senator, during these hearings on this supplemental bill or later for fiscal year 1960?

Senator CANNON. I think that is concerned with 1960.

Senator STENNIS. I think so, too.

Dr. DRYDEN. Dr. Schreiber, who has appeared before the committee.

Senator STENNIS. Did you get that name, Senator Cannon? You may follow up and develop it. Are you through?

Senator CANNON. Yes, sir.

Senator STENNIS. Senator Martin?

Senator MARTIN. One point I would like to ask if it hasn't already been put in the record by you, as with reference to the general summary on page 2. This is out of the estimates of appropriations for 1959 and 1959 supplemental and 1960.

Senator STENNIS. Yes.

Senator MARTIN. The total on page 2 supported by the total salaries and expenses on page 5, the total for research and development is on page 201 and the total for construction equipment is set out on pages 320 and 321. That would give us about as condensed a general picture as we can get.

Senator STENNIS. Yes.

Dr. DRYDEN. It gives you the 1959 and 1960 picture.

Senator MARTIN. That's right, the 1959 supplemental and the 1960 budget. Could those pages be inserted in the record?

Senator STENNIS. I think it is a good idea and I ask the reporter to insert the numbered pages as called for by Senator Martin at this point in the record by way of summary. In addition, also include pages 202 and 203.

Of course, it is understood we will take up the line items of the 1960 budget later.

(The pages referred to are as follows:)

National Aeronautics and Space Administration

Appropriation summary, fiscal years 1959 and 1960

	Fiscal year 1959				Fiscal year 1960, regular estimates
	Appropriated			Supplemental estimates	
	NACA	NASA	Total		
Salaries and expenses	$78,100,000	$5,000,000	$83,100,000	$3,354,000	$94,430,000
Research and development		50,000,000	50,000,000	20,750,000	333,070,000
Construction and equipment	23,000,000	25,000,000	48,000,000	24,250,000	57,800,000
Total appropriations	101,100,000	80,000,000	181,100,000	48,354,000	485,300,000
Transfers from Department of Defense			154,619,532		
Air Force $57,800,000					
ARPA 67,200,000					
Navy (Vanguard) 25,541,282					
Army (JPL) 4,078,250					
Total obligational authority			335,719,532	48,354,000	485,300,000

Salaries and expenses, fiscal years 1959 and 1960

Page No.		Number of employees			1959 allotments	1960 estimates
		1959	1960	Change		
8	NASA Headquarters	336	486	+150	$4,864,850	$6,409,000
9	Langley Research Center	3,333	3,333		30,683,000	32,724,000
10	Ames Research Center	1,509	1,509		16,487,150	18,352,000
11	Lewis Research Center	2,828	2,828		27,606,000	31,733,000
12	High-Speed Flight Station	322	322		2,833,100	3,354,000
13	Space Projects Center	527	1,247	+720	2,639,600	14,744,750
14	Pilotless Aircraft Station	97	250	+153	1,241,920	3,626,000
15	Patrick Office	3	3		27,400	55,250
16	Western Coordination Office	4	8	+4	49,605	80,000
17	Wright-Patterson Liaison Office	2	2		21,375	22,000
7	Total	8,961	9,988	+1,027	86,454,000	111,100,000
	Funded under "Research and development"					−16,670,000
	Total appropriation				[1] 86,454,000	94,430,000

[1] Includes anticipated supplemental (Classified Pay Act increase) in the amount of $3,354,000.

Research and development programs, fiscal years 1959 and 1960

Page No.	Program	Fiscal year 1959		Fiscal year 1960, regular estimates
		Allotments	Supplemental estimates	
	Aircraft, missile, and spacecraft research:			
205	Support of NASA plant	$338,800		$16,670,000
226	Support of JPL plant	8,156,500		8,156,500
230	Research contracts	5,500,000		8,200,000
	Scientific investigations in space:			
232	Sounding rockets	5,000,000		10,000,000
235	Earth satellites	44,000,000		61,800,000
238	Lunar probes	20,021,750		24,043,500
242	Deep-space probes	16,000,000		22,500,000
245	Vanguard program	25,541,282		
	Satellite applications investigations:			
250	Meteorology	3,400,000		15,000,000
253	Communications	4,700,000		13,000,000
	Space operations technology:			
256	Manned space flight	37,661,200	$20,750,000	70,000,000
260	Space rendezvous techniques			3,000,000
	Space propulsion technology:			
262	Solid fuel rockets	700,000		3,000,000
264	High-energy fuel rockets	7,000,000		17,000,000
266	1-million-pound thrust single-chamber engine	12,000,000		30,200,000
268	Nuclear rocket engines	8,500,000		8,000,000
271	Space engines	300,000		3,000,000
274	Auxiliary power units	500,000		3,000,000
	Space systems technology:			
277	Advanced vehicle systems	500,000		1,500,000
279	Booster recovery systems	500,000		1,500,000
281	Orbiting space laboratories			2,000,000
	Supporting activities:			
284	Tracking and data acquisition	4,300,000		11,500,000
	Total, research and development	204,619,532	20,750,000	333,070,000

Functional breakdown, research and development, fiscal year 1959

Page No.	Program	Contracts for—				Total
		Scientific and technical studies	Prototypes and operational hardware	Operations and technical services	Supplies, equipment, repairs, and alterations	
	Aircraft, missile, and spacecraft research:					
205	Support of NASA plant			$2,000	$336,800	$338,800
226	Support of JPL plant [1]					8,156,500
230	Research contracts	$5,500,000				5,500,000
	Scientific investigations in space:					
232	Sounding rockets	300,000	$3,000,000	700,000	1,000,000	5,000,000
235	Earth satellites	1,000,000	34,000,000	8,000,000	1,000,000	44,000,000
238	Lunar probes	2,100,000	16,521,750	800,000	600,000	20,021,750
242	Deep-space probes	3,000,000	13,000,000			16,000,000
245	Vanguard program [1]					25,541,282
	Satellite applications investigations:					
250	Meteorology	800,000	2,000,000	500,000	100,000	3,400,000
253	Communications	500,000	2,800,000	1,200,000	200,000	4,700,000
	Space operations technology:					
256	Manned space flight	700,000	33,361,200	1,700,000	1,900,000	37,661,200
260	Space rendezvous techniques					
	Space propulsion technology:					
262	Solid fuel rockets	100,000	400,000		200,000	700,000
264	High-energy fuel rockets	2,000,000	5,000,000			7,000,000
266	1-million-pound thrust single-chamber engine	500,000	11,500,000			12,000,000
268	Nuclear rocket engines	2,000,000	6,300,000		200,000	8,500,000
271	Space engines	200,000	100,000			300,000
274	Auxiliary power units	200,000	300,000			500,000
	Space systems technology:					
277	Advanced vehicle systems	500,000				500,000
279	Booster recovery systems	500,000				500,000
281	Orbiting space laboratories					
	Supporting activities:					
284	Tracking and data acquisition	300,000	600,000	3,000,000	400,000	4,300,000
	Total, research and development	20,200,000	128,882,950	15,902,000	5,936,800	204,619,532

[1] Functional breakdown not available.

Functional breakdown, research and development, fiscal year 1959 supplemental

Page No.	Program	Contracts for—				Total
		Scientific and technical studies	Prototypes and operational hardware	Operations and technical services	Supplies, equipment, repairs, and alterations	
	Aircraft, missile, and spacecraft research:					
205	Support of NASA plant					
226	Support of JPL plant					
230	Research contracts					
	Scientific investigations in space:					
233	Sounding rockets					
235	Earth satellites					
238	Lunar probes					
242	Deep-space probes					
	Satellite applications investigations:					
250	Meteorology					
253	Communications					
	Space operations technology:					
256	Manned space flight		$20,000,000		$750,000	$20,750,000
260	Space rendezvous techniques					
	Space propulsion technology:					
262	Solid fuel rockets					
264	High-energy fuel rockets					
266	1-million-pound thrust single-chamber engine					
268	Nuclear rocket engines					
271	Space engines					
274	Auxiliary power units					
	Space systems technology:					
277	Advanced vehicle systems					
279	Booster recovery systems					
281	Orbiting space laboratories					
	Supporting activities:					
284	Tracking and data acquisition					
	Total, research and development		20,000,000		750,000	20,750,000

Fiscal Year 1959 Supplemental Estimates, Propulsion Development Facilities

1. DESCRIPTION AND JUSTIFICATION

The capability of placing large payload satellites in earth orbits or of operating advanced scientific manned and unmanned payloads to the near planets is dependent on the availability of rocket boosters developing over 1 million pounds of thrust. In order to obtain these thrusts with a high reliability the NASA is developing, under contract, a single-chamber rocket engine having a nominal thrust of 1 million pounds. This engine development is expected to be complete in about 4 years.

The development of this powerplant, some four times the size of its largest forerunner, calls for extensive and expensive facilities for its fabrication and testing. The engine development program has been planned to make the utmost use of facilities, such as the Air Force large test stands at Edwards Air Force Base, which exist or are currently being built for other programs. Operated by Rocketdyne, a division of North American Aviation, and its engine development contractor, these stands will satisfy the basic test stand requirements of the NASA engine program. Similarly, use of machine tools installed at Rocketdyne by the Air Force for the ballistic missile development program will be used to obviate the need for large expenditures under the NASA program for new machine tools. However, some additional facilities must be acquired for the million-pound engine development.

In the fiscal year 1959 it will be necessary to provide funds for the adaptation of and additions to facilities presently existing at the test sites the contractor will use in the NASA program. Specifically, facilities are needed for development work on the turbopump, gas generator, thrust chamber, controls, and other items. Proper development of this overall engine requires that each of the components be developed independently and that development must be started on all of the components soon if the final engine development is to be completed within the

allotted time. Testing of the completed engine will be on stands provided by the Air Force at Edwards Air Force Base.

Gas generator and control facilities

A gas generator is used to supply high-temperature, high-pressure gas to power the 65,000 horsepower turbopump which pumps the liquid propellants into the engine thrust chamber. Additional capacity for development and testing of a gas generator of this size and for controlling the rate of propellent flow will be provided so that these components can be built and tested independently of the other components. The facilities which will be modified to provide this additional capacity are located at the Rocketdyne test site in the Santa Susanna Mountains above the Rocketdyne plant at Canoga Park, Calif.

Turbopump test facilities

The turbopump consists of three elements: a turbine and two pumps, one for the oxidant and one for the fuel. Each of these three components must be tested independently to evaluate properly the performance of each. The complete assembly must then be tested and evaluated. A means has been devised to accomplish these tests by adding to an existing Rocketdyne facility at Santa Susanna.

Laboratory and manufacturing equipment

The engine is being designed and parts are to be fabricated at the contractor's plant at Canoga Park. Additions to laboratory equipment, manufacturing support equipment, and modifications to production facilities procured by the Air Force to accommodate parts of the size of this engine are required. The funds NASA is requesting will cover such items as specialized instrumentation; special test consoles; larger tanks, plumbing, and valving; larger steel mounting frames; and special safety equipment.

Thrust chamber and engine test stand

In the fiscal year 1959 funds must be provided to complete the modifications and additions to the Air Force thrust chamber stand 2–A and engine stand 1–A at the Edwards Air Force Base, Calif. Also required for fiscal year 1959 funding are the longest leadtime items to adapt to this program the engine stand 1–B which will have two firing positions. The Air Force has pending a request for authority to build stand 1–B with $4 million of fiscal year 1959 funds.

2. Cost estimate

Rocketdyne, Santa Susanna:	
Gas generator and control facilities	$471,000
Turbopump test facilities	563,000
Rocketdyne, Canoga Park: Laboratory and manufacturing equipment	366,000
Total, contractor sites	1,400,000
Edwards Air Force Base:	
Stand 2–A	219,300
Stand 1–A	944,500
Stand 1–B	636,200
Total, Edwards Air Force Base	1,800,000
Total estimated cost	3,200,000

Senator MARTIN. That gives a general picture and a concise picture of the total amount we are looking at here.

Senator STENNIS. I think the Senator is correct.

Senator Smith has indicated she has a question.

RELATIONSHIP WITH OTHER FACILITIES

Senator SMITH. Mr. Chairman, I'm disturbed, as the rest of the committee seems to be, about this participation in joint effort that we hear so much about.

It sounds very desirable and very good to hear from Dr. Dryden. If, after the staff goes over these hearings and it is not fully clear, would it be too much to ask that Dr. Dryden or Dr. Glennan give us as brief a statement as possible showing us the joint effort, as to what extent it goes, participation of all of the agencies and the benefits that come from them even to the contractors—in percentages if possible?

I am still not clear as to what part NASA plays, what part the Air Force plays, and what part the contractor plays in money and in benefits.

Dr. DRYDEN. You mean in this particular case?

Senator SMITH. Yes, in the overall appropriation.

Dr. DRYDEN. In this overall appropriation.

Senator SMITH. Yes.

Dr. DRYDEN. Yes.

Senator SMITH. It seems to me that the facilities, construction and research and development you may have made clear in your statements. I am just asking the staff to analyze it.

Dr. DRYDEN. Yes. I am trying to understand clearly what you want.

In the case of the facilities we discussed, what we have is this: We are using a contractor who has had a long history of engine development contracts with the Air Force. The Air Force has installed at his plant a lot of tools, a lot of special test facilities, has essentially financed most of the facilities in the Santa Susana test areas.

Now, we come along with something which requires that type of facility. Obviously, we don't want to go off and build new facilities and just put a NASA label on them when the Air Force has facilities which will do the job, except that they need to be modified to some extent. You have to modify an existing test stand, provide a pump test stand, and so on.

There is, of course, the question ultimately of who owns the test stand where the basic test stand was built by the Air Force under their funds and we have put some money in for modifications for one of our contracts.

It is owned by the Government. I think 90 percent of the cost probably came from the Air Force in the first place, and we certainly wouldn't raise any question of the legal title so long as we have the agreement which we do have.

We have letters from the Air Force authorizing the use of these facilities by the contractor in this engine contract.

I don't know quite what tabulations you would like. I think the only program now in which money is put by more than one agency is the Rover program where the nuclear part is carried by the AEC and the nonnuclear part of NASA.

In all of our relations with ARPA, I think the last bits of this are being cleaned up as Dr. Glennan explained.

While we have mutual interest and while we have joint technical committees to follow a program, all the money and the financial management responsibility is one place or the other. We don't have a situation where we have a project that is supposed to be run by a committee from two agencies. Management is in one agency. The money is in the budget of one agency, although we have the technical input from the others.

Now, in this engine contract, we have detailed to our headquarters at the present time Colonel Heaton, from the Air Force. He is actually in the office that is handling this project and he is able to put in the Air Force input in the military interest in that particular engine.

The Air Force is putting no money into the support of this engine development. They are permitting the use of Air Force facilities so that we don't have to go off and build a new set of facilities for North American.

Senator SMITH. That is the answer. That is exactly what I wanted to know for the report.

When a Member of the Senate comes along and asks me if you are both spending 90 percent of the cost for the same thing and what you are getting out of it, I would like to be able to answer, and I thought that the clerk could probably get that into the report for us.

Dr. DRYDEN. I think this is what the record would show: that except for that one case of the nuclear projects that the money and management responsibility is one place or the other.

Senator STENNIS. On this possibility of expenditures overlapping into others in the military—and the coordination and the combined use—I think we will have to get some questions framed up, Mr. Clerk, that cover several phases.

We are not critical of you gentlemen at all.

Dr. DRYDEN. We are very anxious to get the record clear.

(The following information was subsequently provided by NASA:)

FUNDING OF TEST STANDS AT EDWARDS AIR FORCE BASE

1. In programing the million-pound-thrust rocket development, the NASA has taken advantage of the provisions of the Space Act permitting NASA to draw upon facilities and other resources proffered by other Government agencies wherever time and money could be saved.

2. The Air Force has supported this NASA effort by making available suitable Air Force facilities procured for Air Force programs at Edwards Air Force Base and at the rocketdyne plant and test sites which can be shared by or assigned to the million-pound engine program without damage to defense programs. By carefully programing the use of such facilities, all presently foreseen needs of the million-pound rocket development for basic facilities will be met with the exception of one large test stand. The facilities loaned by the Air Force are termed "basic" in that they involve such items as general-purpose machine tools, and fixed structures, such as buildings and test stands with their built-in instrumentations, control elements, and utilities, all of which are intended to have long-term usefulness serving a succession of development programs. However, these basic facilities must be modified to varying degrees to adapt them to the particular needs of the NASA program. Also, certain additional facility items, predominantly of a severable chacter, must be procured for use in conjunction with the basic Air Force facilities. Examples of such items are larger fuel and oxidizer tanks and associated plumbing and specialized instrumentation.

3. The NASA fiscal year 1959 supplemental request for $3.2 million is intended to cover only these additions to and modifications of the basic Air Force facilities in order to satisfy the peculiar requirements of the big engine development. Approximately $1.8 million of this amount will be spent at Edwards Rocket Test Station.

4. For the efficient and timely conduct of this engine development, the contractor needs a complex of three large test stands meeting a combination of criteria as to safety, nuisance, potential, accessibility, power, and water supply and availability at minimum cost. The Air Force large test stand complex at Edwards alone could be made to satisfy all these environmental criteria on time. Fortunately, it also represented the cheapest solution. However, one additional two-position stand had to be constructed to complete a three-stand complex. Although the Air Force had planned to construct this stand in fiscal year 1960

to meet anticipated Air Force needs, the construction date would have to be advanced to match the million-pound engine scheduled need date of October 1960. Consequently, the Air Force, after Department of Defense and Bureau of the Budget reviews, is requesting congressional approval to spend $4 million fiscal year 1959 Air Force funds to construct this stand at once.

5. The NASA urges that the approval sought by the Air Force be granted. Only by exploiting the momentum of Air Force planning and design efforts can this facility be acquired in time to avoid delays in this engine program which is pivotal to the National Space Program.

OCTOBER 24, 1958.

Hon. JAMES H. DOUGLAS,
Secretary of the Air Force, Washington, D.C.

MY DEAR MR. SECRETARY: As I mentioned to you when I met with you the other day, we have given consideration to the method of handling the contract for the million pound single chamber liquid rocket development proposed by you in your memorandum of October 9. Incidentally, we refer to the thrust as nominally 1 million pounds although our specifications will require that the rocket be designed to produce, ultimately, a thrust of one million and a half pounds.

While I appreciate very much your offer to have the Air Force serve as program manager, we have decided, in this instance, to contract directly with the winner of a competitive negotiation for which a bidder's conference was held on October 21. The proposals for the engine contract will be opened November 24. I want you to know that studies carried out under the supervision of the Air Force have been of great value in preparing the invitations for proposals. Further, the Wright Air Development Center Propulsion Laboratory has cooperated fully in supplying a list and an availability schedule of Air Force facilities to be made available for this development. In all of this preliminary effort, Col. Donald H. Heaton of the Aeronautics Division, Office of the Director of Research and Development, and Mr. C. W. Schnare of the Propulsion Laboratory of Wright Air Development Center have served as members of a Technical Advisory Committee for Propulsion organized by NASA. ARPA, the USN, and AOMC also were represented on the committee.

It is our desire to continue to work in the closest cooperation with the Air Force in this development. To this end, we invite you to name a project liaison officer to work directly with the NASA project group on this engine development and to participate in the technical decisions to be made in the management of this contract.

We look forward to your cooperation in permitting the use of Air Force-owned, and, where appropriate, Air Force-operated plant and test facilities. It is our wish not to duplicate Air Force facilities. One of the very large responsibilities of the Air Force liaison officer will be to coordinate the availability of Air Force facilities with the needs of the development program.

In closing, may I point out that our decision in this particular instance does not constitute a decision to follow this method of contract placement for all of our work. Indeed, we now plan to contract with and through your Ballistics Missiles division for a space probe as a follow-on to the three lunar probes which have been or will be carried out by that organization. We propose to make use of every effective method of accomplishing our task—in this instance we have chosen what seems to us to be the best course. May I count on your continued interest and support?

Sincerely,

T. KEITH GLENNAN, *Administrator.*

JANUARY 15, 1959.

Hon. NEIL MCELROY,
Secretary of Defense,
Washington, D.C.

DEAR MR. MCELROY: The NASA has completed negotiations with the rocketdyne division of North American Aviation to develop and test a 1-million to 1½-million-pound thrust liquid propellent rocket powerplant. The test schedules for this engine require the use of the following facilities at the Edwards Air Force Base: Stand 1–A, now existing, starting in March 1960; stand 2–A, which is now under construction, starting in December 1959; proposed stand 1–B, beginning in October 1960. Indications are that these dates can be met if the Air Force schedule and plans to construct test stand 1–B are approved.

The use of all three stands is essential. Since the Air Force has planned to fund and has initiated the planning and preliminary design of test stand 1–B, the NASA has not provided for such a facility.

In view of the national importance of the program to develop a large booster rocket engine, delays in the completion of this project would be detrimental to the program. Therefore, it is recommended that approval be given to the Air Force to fund and build test stand 1–B in support of the NASA development program.

Sincerely yours,

T. KEITH GLENNAN, *Administrator.*

Senator STENNIS. We want to put these questions to you.

I think it will help you as well as us.

Mr. Lehrer, if you will take note of the points that have been raised here—whether there is time to frame it exactly as we want it here now I don't know, because we do have to have an executive session later and this is Friday afternoon and we don't want to call all of you back.

So, if the staff will form those questions and get them over to Dr. Dryden and his associates not later than Monday before we close this record, so that we will have those answers and also ask you, the Air Force, the Army and Navy, and any other agency of the Government to apprise them as to these questions having been raised and have them look at the record and Dr. Silverstein's answers.

If they don't agree with them, we will let them come in and testify.

(The information referred to above is as follows:)

RESPONSES TO QUESTIONS OF SENATE COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES

1. Is there any duplication in the amounts requested in this bill with any activities now being carried on by any other Government agency or department?

There is no duplication in the funds requested with the activities of other agencies. Project Mercury is a National Aeronautics and Space Administration project in cooperation with the Advanced Research Projects Agency and other elements of the Department of Defense. However, the funding is entirely through the National Aeronautics and Space Administration budget. Cooperative arrangements with the Department of Defense reflect the Department of Defense interest and particularly the support of DOD in the aeromedical area and in recovery operations. The facilities for the Jet Propulsion Laboratory are similarly clear cut since the transfer of JPL from the Army. The needs for a national tracking network were developed jointly with DOD and represent a NASA obligation for its part of an integrated tracking network.

2. Can the facilities for which funding authorization is requested in this bill be utilized by other Government agencies or departments?

The tracking facilities, which as indicated above are part of a national tracking network, would be used for tracking of both the National Aeronautics and Space Administration and Department of Defense space vehicles and in that sense would be used by other agencies. Under our agreement with the Army and understanding with the Jet Propulsion Laboratory, other agencies will, with NASA approval, be able to place work at JPL in their areas of particular competence. Any work placed at JPL by other agencies would, of course, utilize any of the JPL facilities required for that work. The propulsion development facilities represent needs related to the 1½-million-pound-thrust engine which are not available at Edwards Air Force Base or other test facilities. These facilities would be available to other agencies just as the facilities of the Air Force and Army have been made available to NASA.

3. What procedure is NASA following to assure joint utilization of its facilities where possible? What procedure is NASA following to prevent duplication of facilities and activities in the space field among Government departments and agencies?

Both the National Aeronautics and Space Council and the Civilian-Military Liaison Committee have contributed to working out these relationships. In the area of facilities, requests as in the tracking program, have been based on joint

studies with the military. In other cases such as in propulsion development facilities, the National Aeronautics and Space Administration first approaches the military with its requirements to determine whether there are existing or planned facilities which can be used. If not, the planning of both agencies are brought into agreement to assure that the proposed facilities will serve the needs of all concerned to the maximum extent possible. Similar relationships exist in the nonfacility field, a prime example being the joint Department of Defense-National Aeronautics and Space Administration development of a national booster vehicle program. Similar joint program development efforts are underway, for example, in the area of guidance and in meteorological satellites.

4. What procedure is the National Aeronautics and Space Administration following to utilize existing Government facilities or organizations to assist in carrying out its space activities.

Use of other agencies has come about in a variety of ways. The National Aeronautics and Space Administration, for example, uses or will use both the Atlantic missile range and the Pacific missile range which are under the jurisdiction of the military services. Tracking facilities are jointly used. An agreement exists and has been implemented for NASA to use the capabilities of the Army Ballistic Missile Division. The aeromedical facilities and personnel of the Air Force, Navy, and Army are being utilized in connection with Project Mercury. The Air Force Ballistic Missile Agency is being utilized heavily for missions in making use of Thor and Atlas. The Smithsonian Institution is being utilized in the optical tracking program. The State Department is utilized to help establish overseas tracking locations. The Weather Bureau enlisted in the meteorological satellite program. The Army Signal Corps Laboratory at Fort Monmouth built the payload for the recent Vanguard III cloud cover satellite. The Atomic Energy Commission is being used to develop nuclear-rocket propulsion engines and auxiliary power units of long life. These working relationships and others are worked out on both reimbursable and nonreimbursable bases as the need arises.

Dr. DRYDEN. I was just going to say I have been reminded that in the preparation of the 1960 budget there was coordination with ARPA and there were a considerable number of millions of dollars of duplication eliminated and the responsibility definitely assigned one way or the other.

Senator STENNIS. That is very fine, and we are really not the ones that have the machinery to eliminate these duplications, but we do have the power through the control of the money.

Are there other questions before we go into executive session?

I have a very short statement here that I hope represents the views of the committee which was put together during the noon hour.

DETECTING NUCLEAR EXPLOSIONS

Senator SMITH. Mr. Chairman, I have one question for the record only.

Dr. Dryden, this morning's New York Times reported that Dr. Bethe has proposed to use satellites for the detection of high-altitude nuclear explosions as part of the inspection system.

While we know you cannot discuss this in detail in open session, would you inform the committee whether you consider this a feasible suggestion?

Dr. DRYDEN. I do. We have been consulted on this.

Senator SMITH. And will you prepare a statement or furnish the record with a statement on it for us?

Dr. DRYDEN. I will.

(The following statement was subsequently furnished by Dr. Dryden:)

FEASIBILITY OF DETECTION OF HIGH-ALTITUDE NUCLEAR EXPLOSIONS BY SATELLITES

Yes, I consider Dr. Bethe's proposal for detection of high-altitude nuclear explosions by means of satellites a feasible one. We have made estimates of the costs of placing in orbit and expected date of availability of certain satellite systems for this purpose.

(The newspaper article is as follows:)

SATELLITES URGED AS ATOMIC CHECKS—U.S. SCIENTIST SUGGESTS THEY COULD BE USED TO DETECT OUTER SPACE EXPLOSIONS

[By John W. Finney, special to the New York Times]

WASHINGTON, February 19.—One of the administration's principal scientific advisers suggests that any inspection system for a ban on nuclear weapons tests should include satellites for the detection of nuclear explosions in space.

This proposal, which would result in a major modification of the inspection system agreed upon last summer by East-West experts, was presented earlier this month to the Senate Disarmament Subcommittee by Dr. Hans A. Bethe. A copy of his secret testimony was made public today by the subcommittee.

Dr. Bethe said it now appeared "entirely feasible" to detect high-altitude nuclear tests with satellites equipped with instrumentation to record the radiations emanating from nuclear explosions.

The problem of high-altitude explosions was considered by the East-West experts in Geneva last summer, but they made no recommendations for detecting such tests. Instead, their proposed inspection system, consisting of about 180 ground and sea stations and planes, was specifically designed for detecting nuclear explosions within the earth's atmosphere or underground.

BETHE URGES EARLY ACTION

Dr. Bethe said, however, that before the current East-West diplomatic negotiations on a test ban were concluded, "something should be settled on the observation of high-altitude explosions."

Since last summer's conference, "we have devised a few methods of observation" of high-altitude explosions, of which satellites seem to be the "best way," he remarked.

His conclusions apparently were based on two high-altitude tests conducted by the United States in the Pacific last summer. In citing the feasibility of satellite detection, Dr. Bethe noted that "in empty space the radiations travel unhindered over terrific distances"—a point that was demonstrated in the two Pacific tests.

Dr. Bethe's emphasis on the necessity for some system to detect high-altitude explosions assumed particular significance in view of the key role he has played in administration discussions of a ban on testing nuclear weapons. As a member of the President's Science Advisory Committee, he has headed a task force that first considered the feasibility of an international ban on nuclear weapons testing and subsequently served as a U.S. adviser at the technical talks in Geneva.

METHODS ARE PROPOSED

Among the methods suggested by Dr. Bethe for restoring the dependability of the inspection system were these:

Placing seismographs in 6,000-foot deep holes such as dry oil wells, thus eliminating the surface, background noise that disturbs the detection of earth shock waves from either an explosion or an earthquake. Theoretical predictions indicate this would improve the detection capability "by a substantial factor," he said.

Supplementing the 180 manned stations with unmanned seismographic stations placed about 100 miles apart.

Putting 100 seismographs at each control post, instead of the recommended 10 machines, thus eliminating random disturbances of the machines.

Use of seismographic machines that would be specifically designed to detect shock waves traveling along the surface of the earth. The proposed inspection system was designed primarily to detect the motion of shock waves that travel into the earth and return to the surface.

Dr. Bethe expressed the opinion that a combination of these four steps, or perhaps any two of them, would "bring us back to the original capability" of detecting underground explosions.

In releasing the testimony, Senator Hubert H. Humphrey, Democrat of Minnesota, subcommittee chairman, said it was apparent that "political problems, not technical obstacles, are the main roadblock to an agreement on the suspension of nuclear weapons tests."

Senator SMITH. Thank you.

Senator STENNIS. Before we go into executive session, I would like to make a statement here that I believe will reflect the views of all the committee even though we didn't have a chance to formally confer during the lunch hour.

It appears to me that the NASA has gotten off to a spendid start and is pushing through projects of vital importance. It is very apparent in this showing here.

The program it administers is expensive. The testimony given here indicates that these key officials are cost-conscious—that they are going to make every effort to avoid duplication of effort and other wasteful practices.

The question of a space program is not whether we can afford it, for the answer is that we cannot afford to run second in the world race for knowledge and technology in man's last frontier.

The hearings of the last few days have given the subcommittee an idea of both the progress made and the problems encountered in the aeronautics and space program.

This initial series of hearings has given the subcommittee a constructive view of the program entrusted to NASA.

I am emphasizing this because it is not understood by the public generally. It is not fully understood by all of us here and other Members of the Congress. It is spoken of in jest by some and in fear and awe by others—and a lot of people are very seriously questioning the advisability of trying to go too far into outer space.

The witnesses, key officials of this agency here, with candor and sincerity, answered the questions time permitted the subcommittee to propound.

We have obtained the information on which our recommendation for the authorization for supplemental appropriation for fiscal year 1959 can be based.

Soon the committee intends to review the authorization for the 1960 program in full detail, and at that time, many unanswered questions and perhaps some appsehensions about our space program will be discussed and explored fully.

I commend you gentlemen for being so well prepared here on this matter and I thank all of you for your testimony and those of you who didn't testify we thank you, too, because you came here and were ready and prepared.

We want to try to respect your time and not send for you unless we really need you and you will be frank with us and we will adjust ourselves the very best we can to your convenience.

You mentioned there about someone coming out to visit your installations. I would certainly like to go and I know others would, too, and maybe we can. I am going to ask Mr. Lehrer to make a special effort, he and Mr. Smith, who is also going to help you on this committee, to visit some of these installations as soon as they can.

Is there anything anybody else wants to say in opposition?

(No response.)

Senator STENNIS. Does any member of the committee have anything else to say?

(No response.)

Dr. DRYDEN. I would like to thank you for a very helpful statement and say we will be very glad to see you at any time or come over here and talk with you.

Senator STENNIS. Thank you, Dr. Dryden.

Senator WILEY. Tell those youngsters of yours to get into the discovery line and find this new energy, whatever it is.

Senator STENNIS. I want to make sure to say this: Dr. Dryden was the Director of NACA, which was taken over by NASA.

If there is nothing further, we will ask our visitors to kindly excuse themselves and we will have an executive session.

(Whereupon, at 3:35 p. m., the subcommittee retired into executive session.)

[Executive Hearings as Cleared by the National Aeronautics and Space Administration—Classified Information Deleted]

Senator STENNIS. We will follow the pattern of letting you make your presentation, and then the committee will have a chance to ask you some questions at the roundtable here.

Dr. DRYDEN. We will take the complete record, and we hope that a great part of it can stay in an open record, but we found it much simpler to proceed with the clerk taking everything down and letting us take the things out.

Senator STENNIS. Yes, you will be given a chance to go over the record.

TESTIMONY OF IRA H. ABBOTT, ASSISTANT DIRECTOR OF RESEARCH (AERODYNAMICS AND FLIGHT MECHANICS), NASA

Mr. ABBOTT. Thank you, Mr. Chairman.

Senator STENNIS. This is Mr. Abbott?

Mr. ABBOTT. Yes. You have been hearing mostly in these hearings about NASA's plans for space programs and projects. I would like to talk to you about some of the basic and applied research which is being conducted at NASA research centers, the former NACA laboratories.

Here we conduct both basic and applied research in such broad fields as aerodynamics, flight mechanics, propulsion, structures, and materials.

There is a certain difficulty in making a presentation about a very broad area of research which covers both the basic and applied aspects.

I would like to point out that one of our most serious responsibilities is to do the supporting research that is necessary to support the space efforts of NASA and ARPA, in the projects in which they are interested today and tomorrow, and to support the aeronautical efforts of both civilian agencies and all the military services. We have another responsibility, no less serious, and that is to look far into the future and try to lay the basic grounds for the projects of many years hence.

Accordingly, I find myself very much in sympathy with some of the questions of Senator Wiley, and it is part of our serious responsibilities to look far ahead, to conduct basic research.

However, I find it easier to talk about our research in relation to some of its applications.

As this first chart shows, the research at the NASA research centers is applicable to all types of aeronautical and space vehicles, including helicopters, vertical takeoff and landing airplanes, transport airplanes, supersonic fighters, supersonic bombers, and hypersonic airplanes. I think I had better distinguish between supersonic airplanes and hypersonic airplanes.

We ordinarily think of a hypersonic vehicle or airplane as a vehicle which flies faster than about five times the speed of sound, or to put

it in round numbers, an airplane which would fly faster than about 1 mile per second we would call a hypersonic airplane.

We also do research applicable to missiles of all types, but more especially ballistic missiles and antimissile missiles, satellites, and space craft.

It is obviously out of the question for me within a reasonable length of time to discuss all these applications; so to provide a change in pace from the space activities you have been hearing about, I have selected three examples: One a supersonic bomber, and two types of advanced hypersonic airplanes.

I will, of course, be happy to try to answer any questions you may have about any of the other research.

Now turning first to the supersonic bomber. Presentday operational bombers, such as the B–47 and the B–52 cruise at about 500 miles an hour. The B–58 is not yet operational. [Deleted.]

The B–58 has a supersonic dash capability. [Deleted.]

Now the Air Force has had a requirement for a number of years for an all-supersonic bomber. That is a bomber which would take off, fly the entire distance to the target [deleted], and return, without refueling, at supersonic speed.

Refueling would, of course, increase the range of this bomber.

Several attempts to design such a bomber failed. The research information, the state of the art, was just not sufficiently advanced to permit the range to be obtained.

My next chart illustrates the problem that is facing the bomber designer. I have plotted on this chart range in miles against speed in miles per hour. This upper curve represents the B–52 airplane. You will see it has a very good range [deleted] at a speed of about 500 miles an hour, and naturally cruises for best range at this speed.

The B–58, on the other hand, which is shown by this line here [deleted] has a range which is somewhat less than [deleted] that of the B–52. The reason for this reduction in range at this same speed is due to the configuration changes that were necessary for the B–58 to enable it to be able to fly supersonically. [Deleted.]

You will also notice that the range of the B–58 falls off rather rapidly with speed. [Deleted.]

Now, if we are to fulfill the Air Force requirement for an all-supersonic bomber, we must satisfy a condition out here, that is, we must have a very good range. [Deleted.] I think you can see that this would be quite an achievement.

Now, this range depends on only three things: One is the aerodynamic efficiency of the configuration. Another factor is the propulsive efficiency, and the third one is the structural efficiency. These are all items on which we conduct research at the NASA research centers.

We realized this problem very early, quite a few years ago. We were already doing research on all these efficiency problems in this general speed range. [Deleted.]

As this research began to show promise of paying off someday, we increased the intensity of the research in these areas, and gradually worked into a generalized research program of a rather intensive nature to produce the information that would be required for a design of such a machine.

This next chart illustrates a possible configuration of such a bomber, and also illustrates some of the problem areas on which we have been working in our generalized research program. We have studied, for instance, the various shapes and arrangements of wings, control and stabilizing surfaces, fuselage and engine air intake, in order to obtain the high aerodynamic performance that is required, and to combine this performance with the stability and control requirements to permit flying such a machine satisfactorily over its complete speed range. [Deleted.] This has been a very hard job.

Propulsion research of a very advanced nature was required to provide the design information that was needed to design the advanced engines and after-burners that are required to propel such a machine, and we have been working on those problems. [Deleted.]

After only a few minutes of flight, the wings and other critical portions of the structure would reach the temperature of a baker's oven.

Senator STENNIS. Of what?

Mr. ABBOTT. A baker's oven, the temperature at which you bake biscuits.

This has caused numerous problems with regard to the design of structures suitable for withstanding these temperatures and of materials from which to make these structures. We have had intensive generalized research programs underway in such fields. [Deleted.] At supersonic speeds it is necessary to assist the pilot by means of automatic and semi-automatic stabilizing, control, and navigation equipment. This brings in problems regarding the compatibility of the airplane, the electronics equipment which has to be in it to fulfill these purposes, and the capabilities of the pilot. We have been conducting research on such problems, also. [Deleted.]

This generalized research produced information sufficient so that the Air Force was enabled to enter into a contract with North American Aviation something over a year ago for the development and design of the B–70 bomber.

Since that time we have been continuing our generalized research program to gather further information for the refinement of this airplane and our future high-speed airplanes, and we have also been working very closely with the Air Force and with the contractor, North American Aviation, to study the specific problems associated with the design of this particular weapon in order to permit the Air Force and the industry to produce the best possible weapons system that can be designed at this time.

We have been gratified in doing this to think that this work may also have applications to civilian use as well. We can foresee the rather definite possibility in the future that planes of this general type, but transports instead of bombers, should permit us to fly some day from Washington to London or Paris in less than 2 hours. We would like to think that our work is leading to such possibilities. [Deleted.]

I would like to turn to the first of the hypersonic airplanes, the X–15, about which Dr. Dryden said something this morning.

The X–15 really got started in a sense in 1952. In 1952, the NACA undertook research to study the problems of flight at hypersonic speeds in the earth's atmosphere and of flight in space, which was not a very creditable thing to do in some quarters in those days.

By 1954 this exploratory research had reached the point where we were able to propose to the Air Force and the Navy the construction of a research airplane, which is the X–15, to explore the problems of flight at speeds on the order of six or seven times the speed of sound in the earth's atmosphere, and some of the problems in space; through just reaching out into space, as Dr. Dryden described it, as a fish jumps out of water.

This is a good example of NACA, now NASA, military services, industry cooperation, and was one more in the long chain of research airplanes which had been built and flown in this same manner since the time of the last war.

I have a model here of the X–15 airplane. It looks deceptively conventional. However, there are a few things I might point out about it.

If we consider the whole fuselage from about this point to the rear, for instance, it resembles a ballistic missile more than it does an airplane, in that the entire interior of this fuselage is composed of propellant and oxidizer tanks, plus the rocket engine in the rear end.

You might also notice the rather unconventional tail arrangement with the thick triangular shape of some of these tail surfaces. The skin of this airplane is also constructed of rather thick plate of a high nickel alloy called Inconel X, which retains most of its strength at temperatures at 1200 degrees Fahrenheit. [Deleted.]

There are many more unconventional features about the airplane. You notice the location of the pilot's compartment up here, the region just behind the compartment is used to house the research instrumentation and auxiliary capability. We will pass this model around, if you wish.

Now, the first of the airplanes has been completed and has been moved to Edwards Air Force Base from the contractor's plant, and initial flights on this airplane will begin in the very near future.

Just as Dr. Dryden described on Project Mercury, we are not going to take this airplane up in a full power flight to reach its maximum capabilities the first time. We are going to go at this as we have in the previous research airplanes, in a progressive buildup of speeds and altitudes with a careful analysis of data and conditions from each flight to give us assurance that we can make the next step.

However, I do have here in the next chart a typical flight of the X–15 when we do reach the stage of full power flight.

The airplane will be taking off from Edwards Air Force Base in California, carried under the wing of a B–52 mother airplane. The B–52 will fly carrying the X–15 under its wing up to the vicinity of Wendover Air Force Base up near the Utah-Nevada boundary, up in here. By the time it reaches Wendover——

Senator STENNIS. Pardon me, what boundary?

Mr. ABBOTT. Near the Utah-Nevada-Idaho boundary, for that matter, nearly in the corner there.

By the time the mother airplane has reached Wendover, it will be at high altitude for the B–52 airplane. At this point the X–15 will be dropped from the B–52, its rocket engines will be lighted, and it will climb rapidly, as shown here. At some point along this flight path the fuel will be entirely exhausted, just as in the case of a ballistic missile, and from there on the airplane will continue upward on its own momentum until it reaches a peak altitude. [Deleted.]

Then it will return into the earth's atmosphere.

Now, from the time where the engines stop up over this peak, back to the time where the airplane essentially enters the atmosphere, it will be in weightless flight, and the pilot will experience weightlessness for several minutes.

Up here, outside the atmosphere in a near vacuum, the aerodynamic controls on the airplane will, of course, be useless because there is no air, or essentially no air, for them to operate on. Controls such as those that will have to be used in space will be used to orient this airplane and to permit it to reenter the atmosphere at the right attitude.

We studied this problem, and the result of this research is that small rockets are located on the wing tips and fuselage of this airplane controlled by the pilot to permit him to control the attitude of the airplane.

When the airplane reenters the atmosphere, it is subjected to very high heating, and it is about at this point that the airplane will reach its maximum temperature. [Deleted.] This is perhaps the most serious problem in connection with the design and construction of the whole airplane, and a great deal of research was required in order to permit aerodynamic configurations to be worked out to reduce the number and intensity of the hot spots and to find the right materials, the types of structure that could be used to withstand this heating, and some excellent work on the part of the contractor in learning how to fabricate this unusual material.

As Dr. Dryden mentioned earlier today, the airplane project has served many useful purposes, one of which is to focus on one project a great deal of research all the way from basic fundamental research up to such things as the fabrication of unusual materials into practical shapes in the shops. This whole extension of the state of the art is necessary in order to make these advances.

After entering the earth's atmosphere, the airplane slows down, flies back to Edwards Air Force Base where it will land. [Deleted.]

Senator WILEY. Is this all a pipedream, or is it an actuality now?

Mr. ABBOTT. This airplane exists. It is now at Edwards—the first one is now at Edwards Air Force Base being prepared for the first flight, as of this moment. You are very welcome to come out and see it. I hesitate to——

Senator WILEY. It hasn't gone yet?

Mr. ABBOTT. It hasn't gone yet.

Senator WILEY. Oh, well, then it is a pipedream. [Laughter.]

Mr. ABBOTT. Yes, it is a pipedream. It is a pipedream exactly like the X–1 was a pipedream in 1947.

Senator WILEY. Dreams, dreams, that is what the future is made of. I told you that a few minutes ago.

Mr. ABBOTT. I told you that we believed in it.

Senator CANNON. Mr. Abbott, isn't the first flight scheduled for this year?

Mr. ABBOTT. I hesitate to give these schedules because they are always slipping on us, but we expect to make the first captive flight under the wing of the B–52 very soon, and the first drop flight however, without lighting of rockets, about 2 or 3 weeks later.

Now, partly this depends on whether we continue to find unexpected things in the airplane; partly it depends on how much it rains in California.

In 1956 we were very much involved in our research centers with the problems of the X–15 airplane in assisting North American Aviation in the problems which they were encountering in the development of it. At that time the X–2 research airplane reached a maximum altitude of about 25 miles in one flight, and a maximum speed of between 2,100 and 2,200 hundred miles an hour in another flight. This is still the highest and the fastest that man has ever gone.

It became evident to us at that time that we should take stock of where we stood, and where we wanted to go.

We did that, and our conclusions, I think, can be illustrated on this next chart.

I have plotted here altitude in miles against speed in miles per hour. This multicolored ribbon running up through the chart shows the area in which it is possible to have continuous level flight. Above this area, say up into here, the air is too thin, we are too far out in space for the wings of an aircraft to support its weight.

Down here, below this corridor, the air is so dense that the loads, the pressures on the aircraft and the temperatures which would be reached would be too high for any foreseeable structures to withstand continuously.

So we do have a corridor in which it is possible to have continuous level flight.

Now, way down here in the lower left-hand corner in white I have outlined the area which can be covered by the B–70 airplane, when we get it, and you see that on this overall plot the conditions of flight for the B–70 seem to be rather restricted, although it is a most notable advance in aeronautics.

Now, above the B–70 area in red, I have shown the area which can be covered by the X–15 airplane.

Now, of course, as illustrated in the previous chart, the X–15 is not confined to this corridor. It can zoom out of it to high altitudes and then back into the corridor, but when it does this, it is not in sustained flight. It is flying more like a ballistic missile, and it cannot fly continuously up in this region. It can only zoom up and then sort of fall back; so that this red area does represent the area of sustained flight for the X–15 airplane.

Now, looking farther ahead, we have this whole yellow area going all the way up to extremely high altitudes, and out here at speeds all the way to satellite speeds in which continuous flight within the atmosphere is possible.

Studies of this area, theoretical studies, plus experimental studies in our laboratories that we were able to make, indicated that the most serious conditions in this corridor existed at speeds between about 12,000 and 14,000 miles an hour.

In this region, the heating is the greatest in the entire corridor. That is, if we were able to design an aircraft to fly at speeds of 12,000, 14,000 miles an hour, it would then be able to fly anywhere in this corridor, all the way from down here to satellite speeds outside the atmosphere.

So this is a most serious design problem, and this was obviously a field to attack.

We were already doing generalized research on such problems, and in 1957 the Air Force and the NACA agreed that a rocket-power hypersonic glider should be designed as a research airplane to study this problem. This is the objective of the joint Air Force, NACA, now NASA, Dyna Soar I project.

The next chart shows a possible configuration for the Dyna Soar I vehicle. Other configurations are under study.

This vehicle is boosted from the ground by boosters, and the vehicle booster combination might look as shown here. The size of the boosters would depend upon the speed at which one wished to boost the vehicle, which in turn would depend upon the part of this corridor which one wished to explore.

A typical booster might appear about as shown here.

I have shown here a typical trajectory for Dyna Soar I, in this case the vehicle would be launched by a booster about as shown on this insert, and boosted to a high altitude. [Deleted.] At this point, the booster would cut off. The vehicle would then glide in the upper reaches of the atmosphere back to a landing point. [Deleted.]

The vehicle has capability of maneuvering much like an airplane because it is flying within the atmosphere.

The landing of this vehicle is such, the configuration and wing loadings are such, that it will have better landing characteristics than the X–15. [Deleted.]

[Deleted.] Vehicles such as this pose very many difficult research problems. In fact, they are the most difficult research problems that we foresee in the general area of aeronautics or reentry of space vehicles. [Deleted.]

This type of airplane poses many serious problems in aerodynamic configurations to keep the heating rates as low as possible and avoid hot spots in materials of which the vehicle is built, and of the types of structure used in the vehicle to permit retaining strength at very high temperatures with the distortions that will occur when parts of the vehicle are heated to high temperatures while other parts of the vehicle are cold.

There are also many problems of stability, control, navigation, guidance, and this sort of thing. We visualize a manned vehicle assisted by a certain amount of automatic control and stabilizing equipment. These problems are all being studied.

In spite of the very difficult problems we foresee for this, the research has advanced to the point where we believe that such a vehicle is not only feasible, but highly desirable as a continuation of the research airplane program to explore this most difficult region of very high speed, and this has now progressed to the point where the Air Force is conducting a design competition on this vehicle.

That completes my remarks. I would be glad to try to answer any questions about any part of this you may wish to bring up.

Senator STENNIS. I have only one question, and then we will proceed around the table.

How far do you carry this research for the Air Force? You have been carrying on this project under the old NACA?

Mr. ABBOTT. Yes.

Senator STENNIS. How far do you go with it, and do you do all of their similar research?

Mr. ABBOTT. No; I cannot say that we do all of it by any manner of means.

Senator STENNIS. Well, a major part of it?

Mr. ABBOTT. The research inputs come from all over the scientific community.

Senator STENNIS. Let's abandon that part of the question.

How far do you carry it, before you turn it over to them—just what is that situation?

Mr. ABBOTT. Perhaps I can answer that question best by saying what happens in a typical case.

Senator STENNIS. Please do.

Mr. ABBOTT. And it doesn't make much difference whether it is a B–70 bomber or the X–15, or the Dyna Soar, or whatever it is.

Of course, we are doing laboratory research. At first, we do not see any application for it, we are working out in the wild blue yonder, we are working on pipedreams, if you will. This work is not very intensive, but it is going on all the time in various fields.

As this work goes ahead we begin to see, and other people begin to see, some possibilities of applying this to something, the exact details of which are at this moment very vague.

When this occurs, we increase the intensity of this research, try to get it down to brass tacks, so to speak, and, of course, we are intimately associated with the Air Force and the Navy all the time. They know what we are doing and we know what they would like to do, and it becomes apparent to all of us that we are really on the track of something. Now, sometimes we are not, but in a typical case we find we really are.

At this point we start a very intensive program to try to solve all the problems we can foresee in this application in the areas in which we do research. In the areas in which we do not do research—and there are many such areas—the Air Force or Navy, as the case may be, will get research done in those areas by contract with other people to supplement us, and this is a very important contribution to the whole subject. Then we continue with it.

Senator STENNIS. You take this all into consideration.

Mr. ABBOTT. And it eventually reaches the point where there is enough information where a contract can be let for somebody to design and develop this thing.

After this happens we continue to work with the Air Force or the Navy, as the case may be, and with the contractor.

In many cases testing exact configurations, consulting with many people around the table, not once but many, many times, so that we are intimately in contact with both the military and the contractor right up to the time the airplane flies, and after that, with whatever problems they have with it.

Senator STENNIS. That is system work——

Mr. ABBOTT. However, we do not design the airplane.

Senator STENNIS. They pick it up there and design the airplane.

Mr. ABBOTT. Yes.

Senator STENNIS. To carry out what you have learned?

Mr. ABBOTT. Yes.

Senator STENNIS. And that system has worked all right with both the Air Force and the Navy; has it not?

Mr. ABBOTT. It has worked extremely well.

Senator STENNIS. Senator Smith.

Senator SMITH. Yes, Mr. Chairman. I have a couple of questions and I would like both of them to have an answer and preface it by an observation, if I may, of either Dr. Abbott or Dr. Dryden.

One of the principal arguments given against missiles replacing manned bombers is that a manned bomber can always be recalled in the event it is determined that an enemy attack has actually not been launched against our country, and hence to avoid inadvertently starting a war. However, a missile cannot be stopped once it has been fired or launched but rather will continue on its flight until it hits the country at which it has been aimed.

In view of this, can you tell the committee what research or any other work has been done on the goal of being able either to perfect devices by which to destroy the missile in flight, or cause it to destroy itself short of the originally intended target in order to avoid starting a war as a result of a miscalculation or erroneous identification?

I know that missiles can be destroyed by electronic devices near the launching pad. But can they be destroyed at long distances, say a thousand miles or more from where they have been launched?

Mr. ABBOTT. Do you want to tackle that, or do you want me to?

Dr. DRYDEN. Well, I might try that.

We do not know of any way of destroying a missile remotely other than by having a destructive charge on board and the radio command signal to blow it up, as you have indicated. This is always done on the ranges for safety purposes.

If you put such equipment on a tactical missile, you reduce its range. I have forgotten; it is a pound, each pound reduces the range 1 mile, or some such figure as this. So that such devices could be installed.

Now, whether you could get a reliable radio command signal at a distance of a thousand miles, I am not prepared to say. We do communicate over such distances by radio, of course. I would think there would be some problems connected with trying to do it at such distances.

Senator SMITH. But, Dr. Dryden, of course we are going to continue with our manned bombers for some time. We have to proceed with our developments and improvements and construction, as well as production. But the time has to come, if I see the future correctly, when we will not have our manned bombers, or at least will rely largely on missiles. My question is, Is there any plan or is there any work being done on such a device that would recall that missile, or since we probably would not want to recall it, to destroy it so that it will not hit the target?

Dr. DRYDEN. I do not happen to know of any active work along this line. I might say that I am one of those who do not believe that you will abandon manned bombers for a very long time, and for a rather simple reason: that it is impossible with any black boxes we know so far to build into it the capabilities of a human brain.

The most dramatic illustration of this was the experience of Bill Bridgeman in flying one of the research airplanes, the D–558–2, when under certain conditions the airplane went into a violent instability. He was able to work around with the airplane and finally recover and

land it safely, but he was shaken up and bruised quite a bit, and I believe it turned out that he had to operate the controls just the opposite from what you thought they ought to be operated in order to get out of this unusual condition.

It is very difficult to think of any combination of black boxes that ever would have brought this airplane back. The human brain can readjust itself to a new situation. It is not easily fooled.

Most missiles that I know of other than the ballistic missile can be fooled in various ways.

Now, a ballistic missile that is wholly dependent on inertial guidance, we do not know anyway of interfering with its flight.

But the human brain is still very important as a part of the whole business, because of the rapidity with which he can change his programing as compared to the way a mechanical or electronic computer can change its programing.

I think you have the situation that you have had in the military field from time immemorial, of the offense against the defense; there is temporarily a gain one way, temporarily a gain another way.

I think we will learn how to take manned equipment into heavily defended territory. If we don't we will probably want the man to go pretty close to the border and release his missile there in some instances.

Senator SMITH. Mr. Chairman, if I may continue. Doctor, I am correct in understanding there has been no research and there is none planned that would lead to the destruction of or the return of a missile. I am trying to clear this in my mind, since I have heard the problem raised so many times.

Dr. DRYDEN. I do not know of any, but this is a question, I think, that Dr. York could answer better than I, because it is in the military research field.

Senator SMITH. Thank you very much.

Senator STENNIS. Thank you.

Mr. ABBOTT. I think I might add to that. This is a very difficult problem which might better be asked of Dr. York, or somebody in the Pentagon rather than us, because this is outside our area of responsibility. But I am not entirely unfamiliar with some of the thinking.

The reason you cited is only one of several reasons why the bomber would still be useful, and in this particular case there are many difficulties involved.

For instance, if you have such a device, you certainly are going to rely on some means of communication, whatever it may be.

The present system in the Strategic Air Force for making sure that a war is not started accidentally is that the pilots are under orders to return unless they receive a positive order to proceed, which is quite a different thing.

Now also, any destruction system which you put in a missile which would be capable of destroying it, once the enemy found out what this destruction signal is, he will then have a perfect defense against all our missiles, so that the whole problem is fraught with a great many difficulties.

Senator STENNIS. All right. Thank you, Senator Smith.

Senator Dodd, any questions?

Senator DODD. I have no questions.

Senator STENNIS. Senator Martin?

Senator MARTIN. Does this plane have a title or a name?

Mr. ABBOTT. That is very similar to the B–70. The B–70 contract has been underway only something over a year now, and its configuration is still changing in detail, and I think it will be most surprising if it looks exactly like that, but it will look something like it. It has been called a Valkyrie by the Air Force.

Senator STENNIS. Are you through, Senator?

Senator Cannon.

Senator CANNON. No questions. I am glad, Mr. Chairman, you brought out the location of the flight of the X–15.

Senator STENNIS. I thought he said the Yukon, and I wanted to make sure.

Senator Wiley.

Senator WILEY. We got an invitation to come over and see what you fellows are doing. I think the chairman ought to not forget that, and to see if arrangements can be made so that as soon as Congress is over, which will be, I trust, in the latter part of July, we might go out there and see what you fellows are really doing.

Meanwhile, you told us before that this was largely conjectural, these distances, and these mileages. [Deleted.]

Mr. ABBOTT. Well, this is merely an example. If you put on a smaller booster it wouldn't go so fast and it wouldn't go so far. If you put on a bigger booster, it will go faster, it will go higher, and it will go farther.

Senator WILEY. That is on the missile?

Mr. ABBOTT. That is on this Dyna Soar I.

Senator WILEY. Yes.

Mr. ABBOTT. For instance, all the way around the world. [Deleted.]

Senator WILEY. Well, now, is that practical?

Mr. ABBOTT. We believe it is. [Deleted.]

I do not think we know how to start designing with certainty a commercial transport to do this. Among other things, when you start designing commercial transports, you have to be sure that you can convince the bankers that this thing is going to keep itself in the air not only physically but financially. I am quite sure [deleted] that with some further research, such a transport will be possible.

Senator WILEY. If it is practical, and your answer is yes, what kind of fuel do you use in that?

Mr. ABBOTT. I think the fuel will turn out to be kerosene or jet fuel. I would be most surprised if we fly a transport on anything else.

Senator WILEY. That is all.

Senator STENNIS. Senator Case, we are glad to have you, sir. We would be glad to have your questions.

Senator CASE of New Jersey. I appreciate your invitation to come with the subcommittee.

I have no questions, thank you.

Senator STENNIS. The carrying plane for the X–15, as I understand it, is a B–52.

Mr. ABBOTT. Yes, sir; it is a B–52.

Senator STENNIS. Well, do you have any other matters now that you wish to cover?

Dr. DRYDEN. This is all. This is the end of the presentation.

Senator STENNIS. Does anyone else in the group have anything else they wish to say?

(No response.)

Senator STENNIS. Are there any other questions from anyone? Mr. Lehrer, do you have anything further?

Mr. LEHRER. No, sir.

Senator STENNIS. Mr. Smith, do you have anything else?

Mr. SMITH. No, sir.

Senator STENNIS. We certainly want to thank all of you again.

We are fascinated by many of the things you tell us, and we are concerned about them. We want to get down to earth, though, on this proposition about building these facilities and their possible duplication.

As I said in my opening statement, I think that no essential dollar should be spared in all of your work, but certainly we ought to make certain there is no dollar wasted.

Dr. DRYDEN. Yes, sir.

Senator STENNIS. And I see these military programs grow, and I seldom hear of anything being abandoned. There is a tendency to just put one on top of another and those costs are mounting and going into billions of dollars. I think that that is the most serious threat to the continuation of a sound program, the military simply building one piece on another, to the extent that we won't be able to finance it, or will have a runaway inflation situation.

If there is nothing further, you are excused, with the thanks again of the subcommittee, and with our previously expressed reservations to ask you for any additional information that we may find necessary and also, we may wish to ask Dr. Glennan back.

Dr. DRYDEN. Yes, sir.

Senator STENNIS. Well, thank you again.

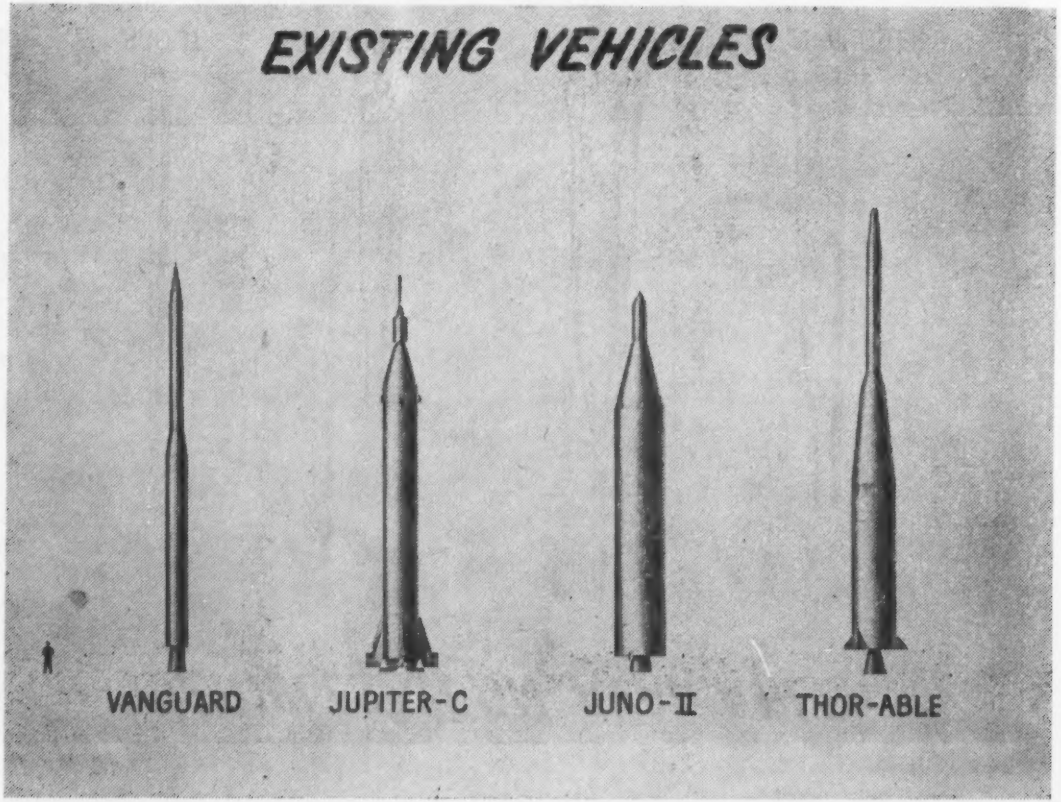
The committee wishes to thank the press for attending today. This has been an excellent attendance, and we appreciate it very much.

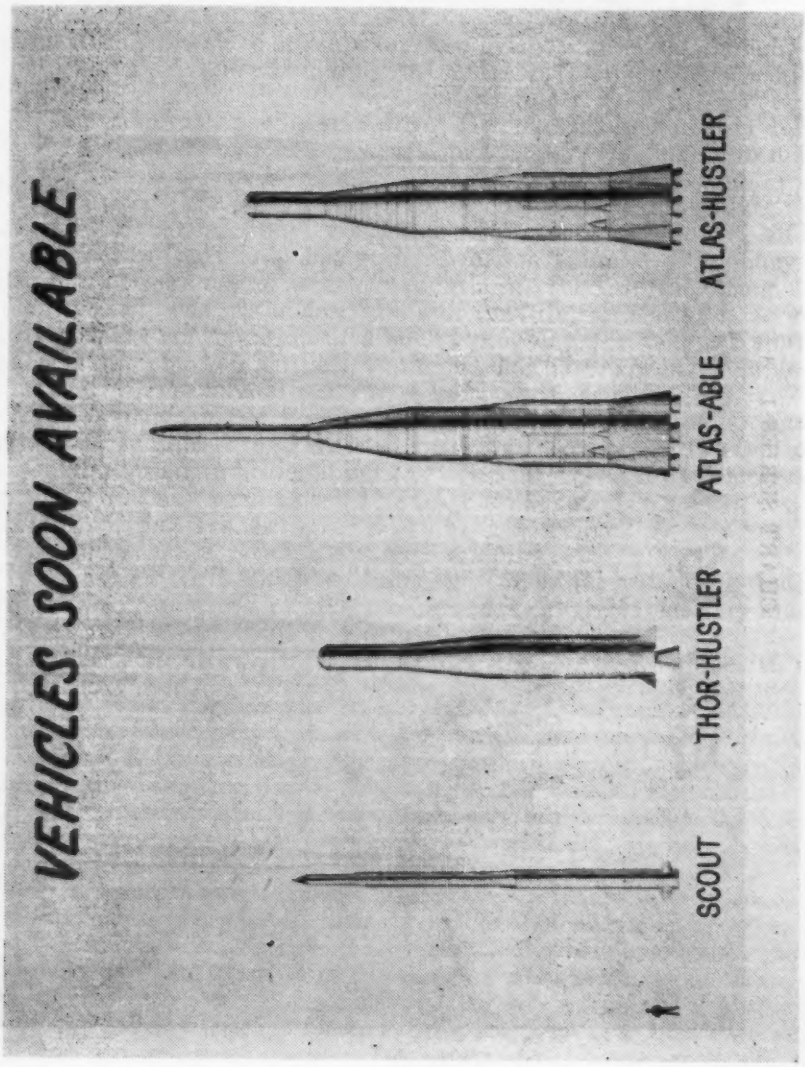
We will recess then, subject to the call of the Chair.

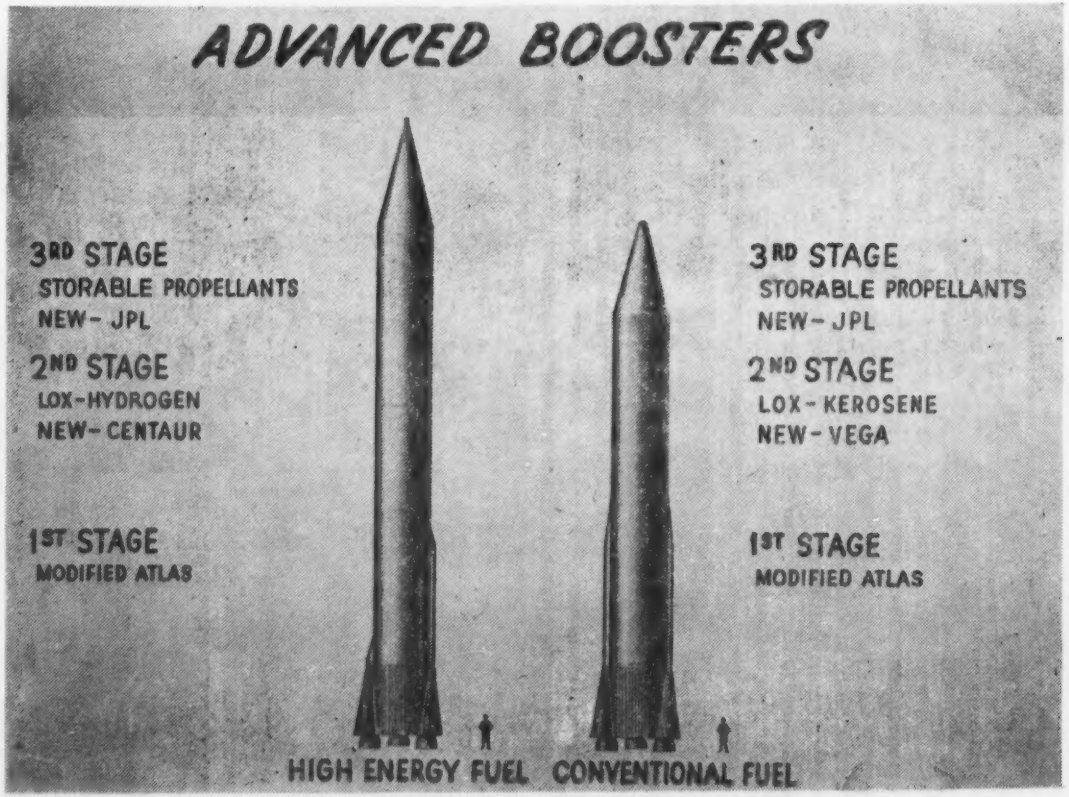
(Whereupon, at 4:30 p.m., the committee recessed, subject to the call of the Chair.)

APPENDIX

CHART SERIES 1




VEHICLES SOON AVAILABLE
SCOUT
THOR-HUSTLER
ATLAS-ABLE
ATLAS-HUSTLER


ADVANCED BOOSTERS
3RD STAGE
STORABLE PROPELLANTS
NEW - JPL
2ND STAGE
LOX-HYDROGEN
NEW - CENTAUR
1ST STAGE
MODIFIED ATLAS
3RD STAGE
STORABLE PROPELLANTS
NEW - JPL
2ND STAGE
LOX - KEROSENE
NEW - VEGA
1ST STAGE
MODIFIED ATLAS
HIGH ENERGY FUEL
CONVENTIONAL FUEL

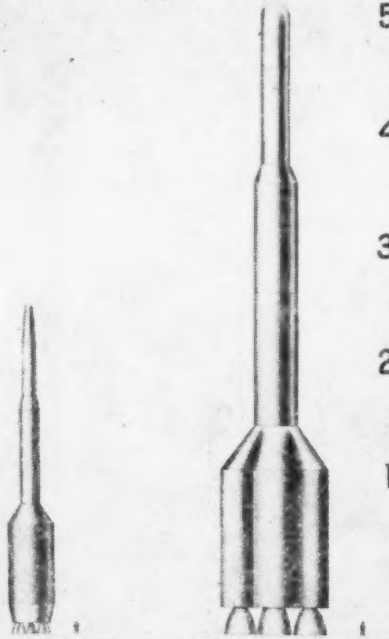
ADVANCED BOOSTERS

4TH STAGE
STORABLE PROPELLANTS
NEW-

3RD STAGE
LOX-HYDROGEN

2ND STAGE
LOX-KEROSENE
MODIFIED TITAN I

1ST STAGE
CLUSTER OF MODIFIED
ENGINES



MILLION POUND
CLUSTER

6 MILLION POUND
CLUSTER

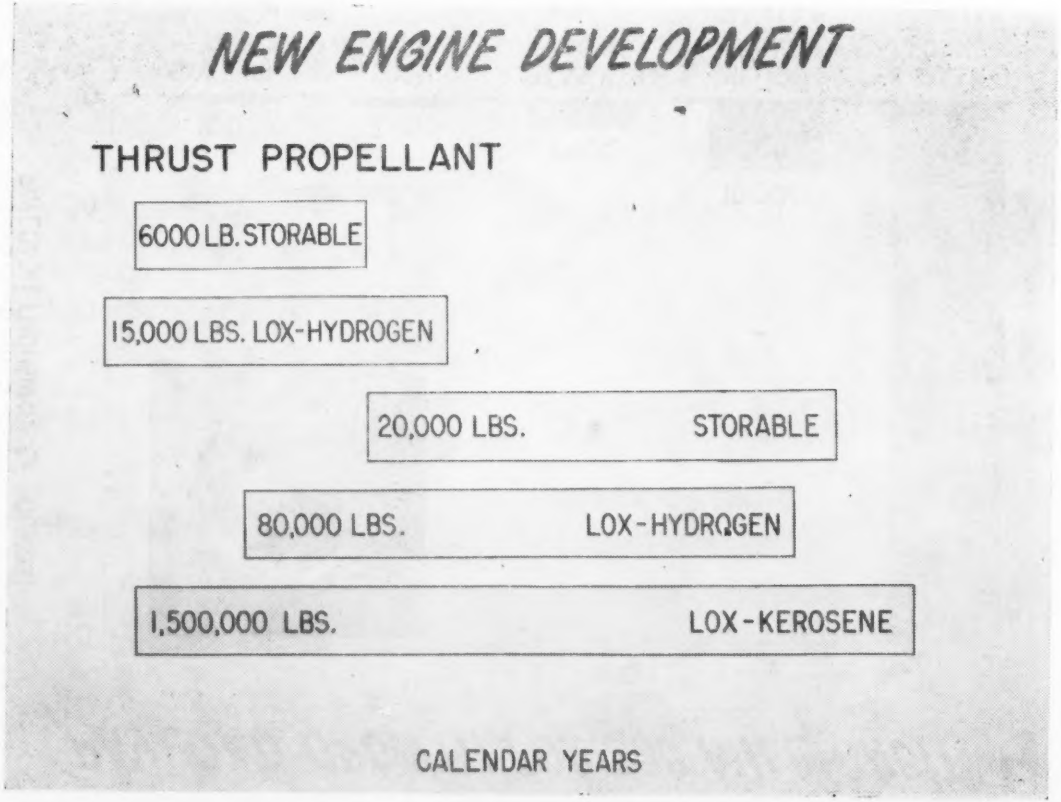
5TH STAGE
STORABLE PROPELLANTS
NEW-

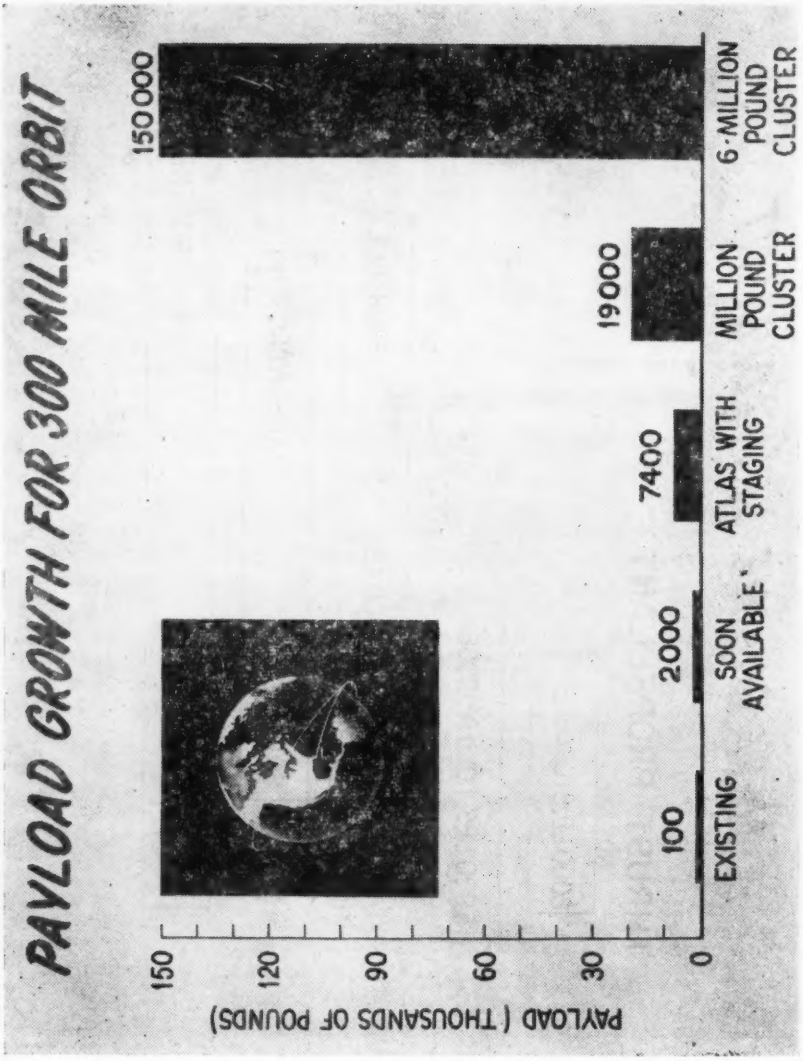
4TH STAGE
LOX-HYDROGEN
NEW-

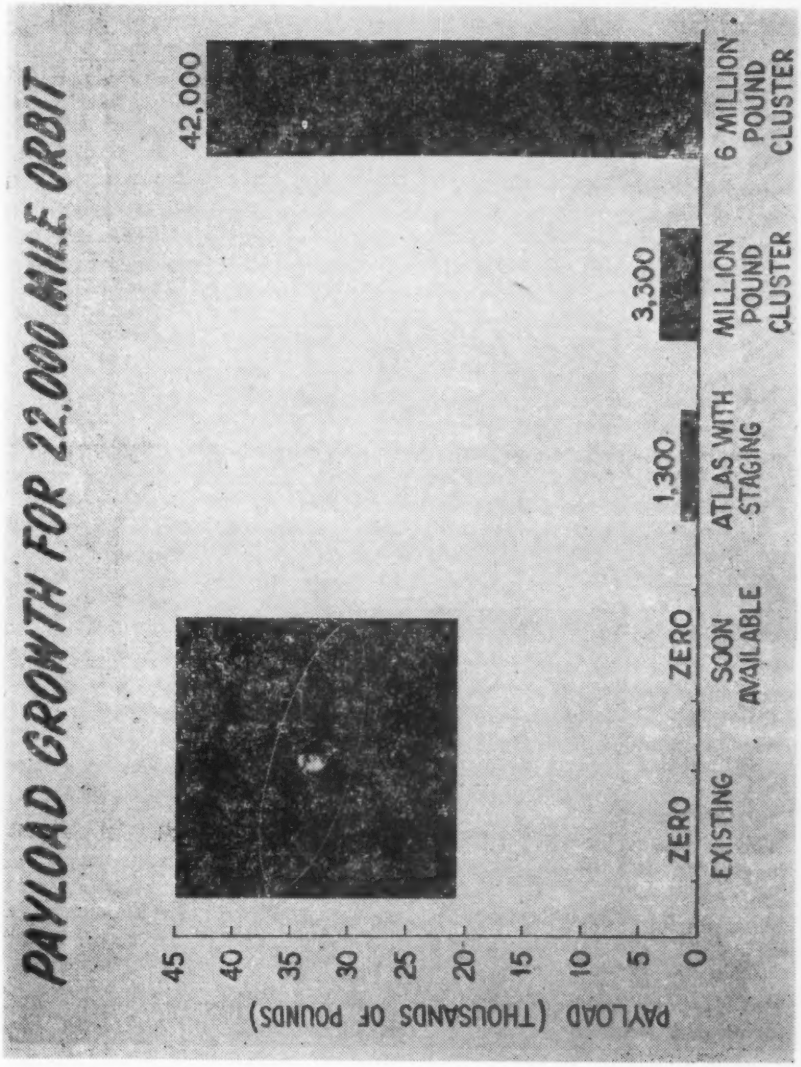
3RD STAGE
LOX-HYDROGEN
NEW-

2ND STAGE
MILLION POUND ENGINE
NEW-

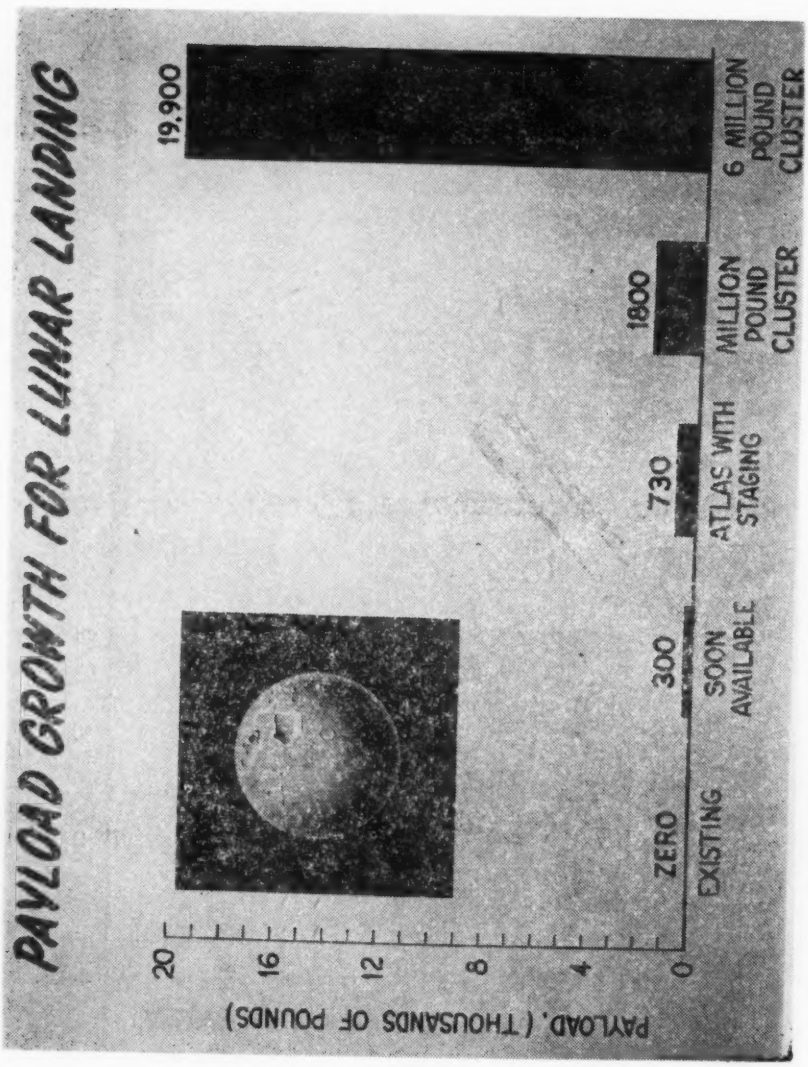
1ST STAGE
CLUSTER OF MILLION
POUND ENGINES
NEW-


NEW ENGINE DEVELOPMENT
THRUST PROPELLANT
6000 LB. STORABLE
15,000 LBS. LOX-HYDROGEN
20,000 LBS. STORABLE
80,000 LBS. LOX-HYDROGEN
1,500,000 LBS. LOX-KEROSENE
CALENDAR YEARS


PAYLOAD GROWTH FOR 300 MILE ORBIT
PAYLOAD (THOUSANDS OF POUNDS)
150
120
90
60
30
0
100
2000
7400
19000
150000
EXISTING
SOON AVAILABLE
ATLAS WITH STAGING
MILLION POUND CLUSTER
6-MILLION POUND CLUSTER


PAYLOAD GROWTH FOR 22,000 MILE ORBIT
PAYLOAD (THOUSANDS OF POUNDS)
0
5
10
15
20
25
30
35
40
45
ZERO
EXISTING
ZERO
SOON AVAILABLE
1,300
ATLAS WITH STAGING
3,300
MILLION POUND CLUSTER
42,000
6 MILLION POUND CLUSTER

36915—59——10


PAYLOAD GROWTH FOR LUNAR LANDING
PAYLOAD, (THOUSANDS OF POUNDS)
0
4
8
12
16
20
ZERO
EXISTING
300
SOON AVAILABLE
730
ATLAS WITH STAGING
1800
MILLION POUND CLUSTER
19,900
6 MILLION POUND CLUSTER

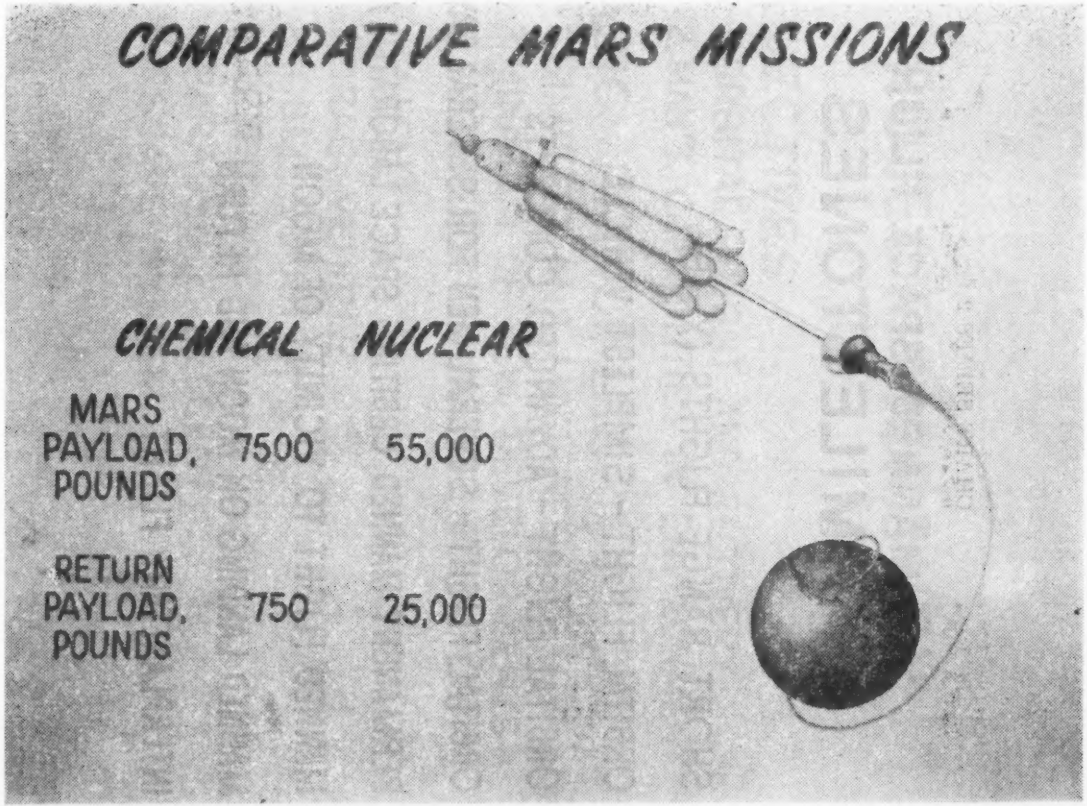

COMPARATIVE MARS MISSIONS
CHEMICAL
NUCLEAR
MARS PAYLOAD, POUNDS
7500
55,000
RETURN PAYLOAD, POUNDS
750
25,000

CHART SERIES 2

MANNED SPACE FLIGHT MILESTONES

A. SHORT RANGE FLIGHTS (X-15)

B. ORBITAL FLIGHT - SIMPLEST VEHICLE

C. ORBITAL FLIGHT - ADVANCED CONCEPTS

D. ORBITAL FLIGHT - SEVERAL MEN FOR SEVERAL DAYS

E. PERMANENT MANNED ORBITING SPACE LABORATORY

F. MANNED FLIGHT TO VICINITY OF MOON

G. MANNED LANDING ON MOON AND RETURN

H. INTERPLANETARY FLIGHT

PROJECT MERCURY

OBJECTIVES

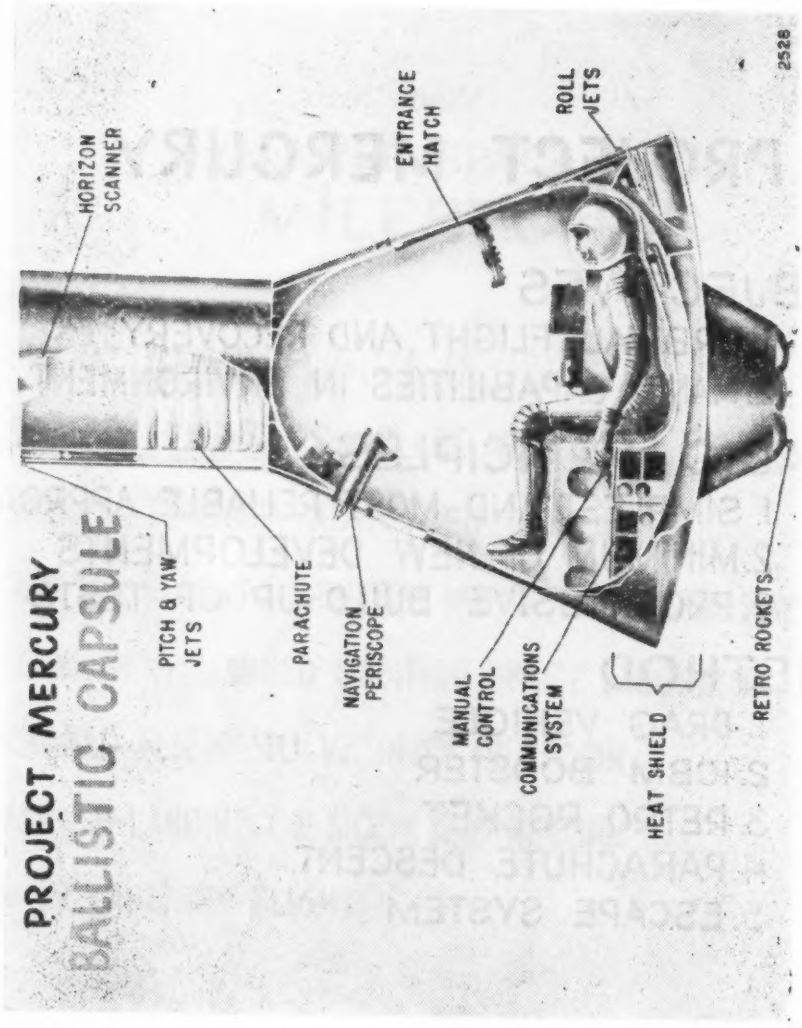
1. ORBITAL FLIGHT AND RECOVERY
2. MAN'S CAPABILITIES IN ENVIRONMENT

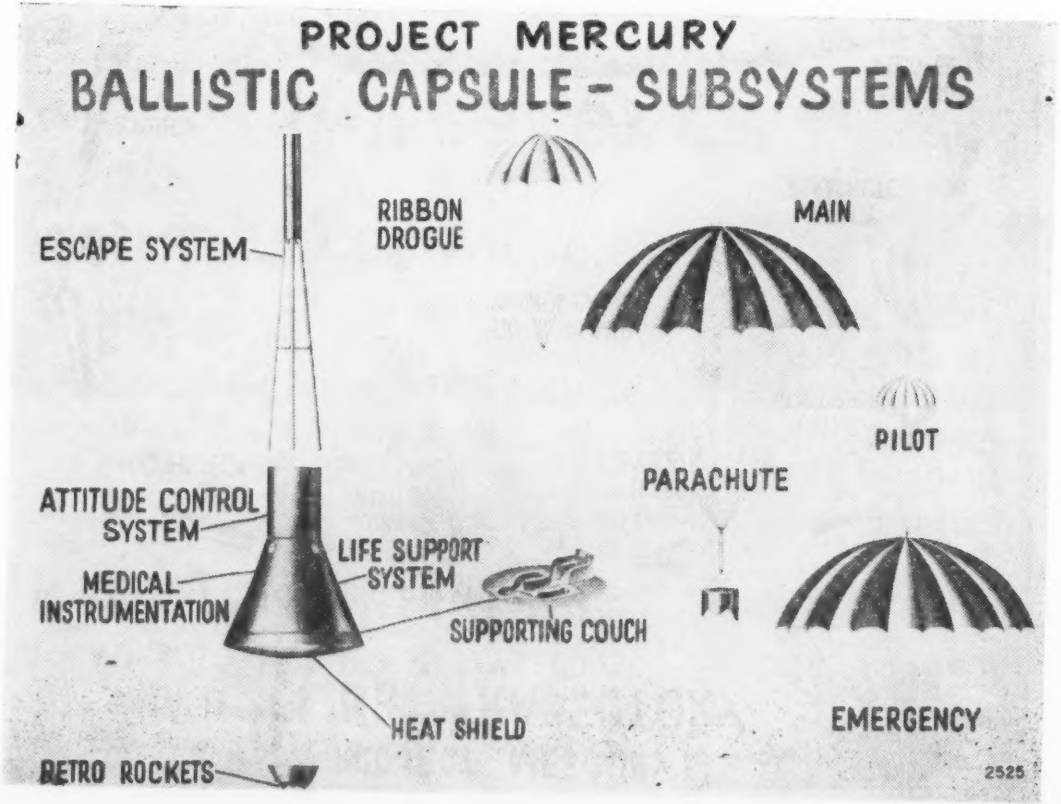
BASIC PRINCIPLES

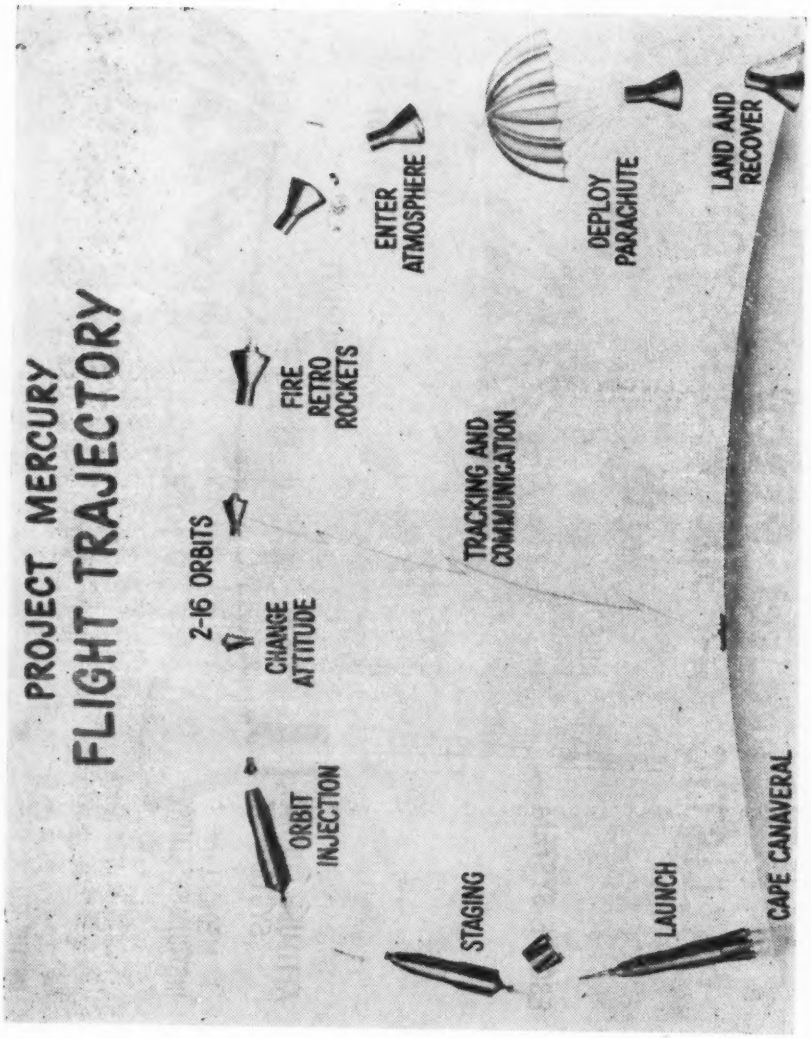
1. SIMPLEST AND MOST RELIABLE APPROACH
2. MINIMUM OF NEW DEVELOPMENTS
3. PROGRESSIVE BUILD-UP OF TESTS

METHOD

1. DRAG VEHICLE
2. ICBM BOOSTER
3. RETRO ROCKET
4. PARACHUTE DESCENT
5. ESCAPE SYSTEM


PROJECT MERCURY
BALLISTIC CAPSULE
HORIZON SCANNER
PITCH & YAW JETS
PARACHUTE
NAVIGATION PERISCOPE
MANUAL CONTROL
COMMUNICATIONS SYSTEM
HEAT SHIELD
RETRO ROCKETS
ENTRANCE HATCH
ROLL JETS
2528


PROJECT MERCURY
BALLISTIC CAPSULE - SUBSYSTEMS
ESCAPE SYSTEM
RIBBON DROGUE
MAIN
PILOT
PARACHUTE
ATTITUDE CONTROL SYSTEM
LIFE SUPPORT SYSTEM
MEDICAL-INSTRUMENTATION
SUPPORTING COUCH
HEAT SHIELD
EMERGENCY
RETRO ROCKETS
2525


PROJECT MERCURY
FLIGHT TRAJECTORY
ORBIT INJECTION
2-16 ORBITS
CHANGE ATTITUDE
FIRE RETRO ROCKETS
ENTER ATMOSPHERE
DEPLOY PARACHUTE
LAND AND RECOVER
TRACKING AND COMMUNICATION
STAGING
LAUNCH
CAPE CANAVERAL

PROJECT MERCURY
MILESTONES

A. CAPSULE CONTRACTOR

NASA ORGANIZED	OCT. 1, 1958
SPACE TASK GROUP FORMED	OCT. 5, 1958
CAPSULE SPECIFICATIONS MAILED	OCT. 23, 1958
BIDDERS CONFERENCE HELD	NOV. 7, 1958
PROPOSALS RECEIVED	DEC. 11, 1958
CONTRACTOR NAMED	JAN. 9, 1959

B. DEVELOPMENT TESTS

WIND TUNNEL TESTS STARTED	OCT. 1958
LANDING SYSTEM TESTS STARTED	OCT. 1958
ESCAPE SYSTEM TESTS STARTED	JAN. 1959

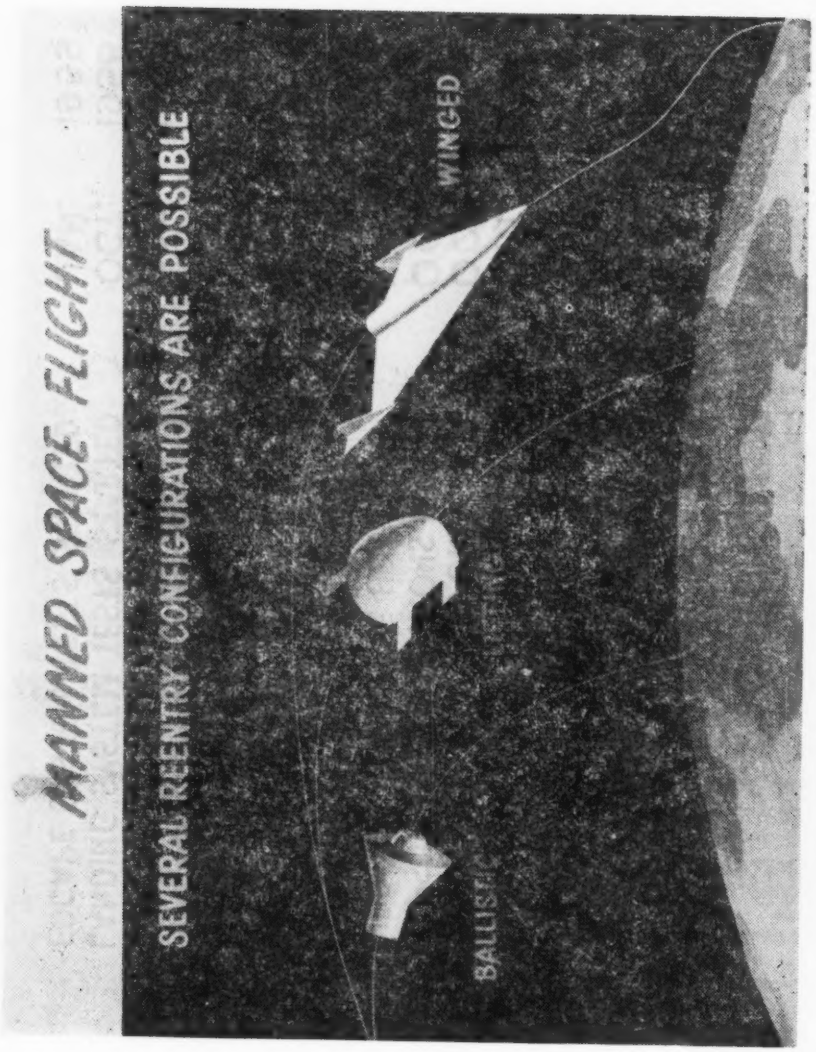
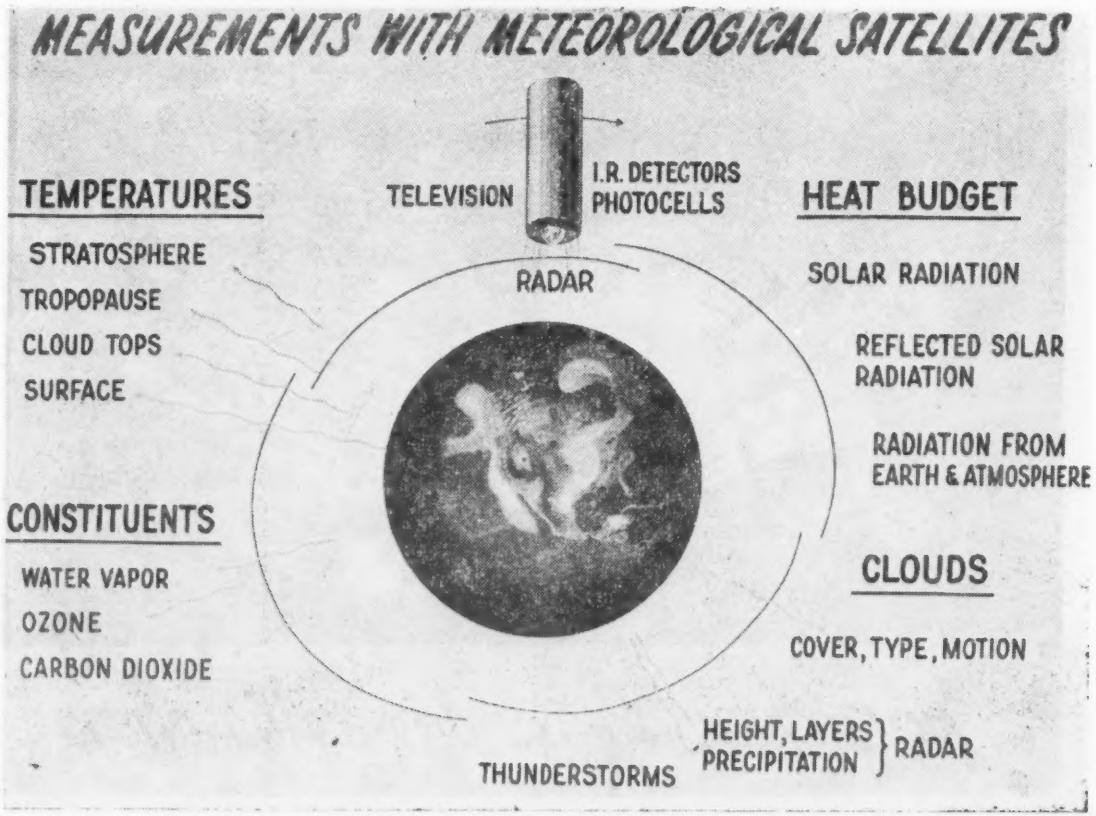


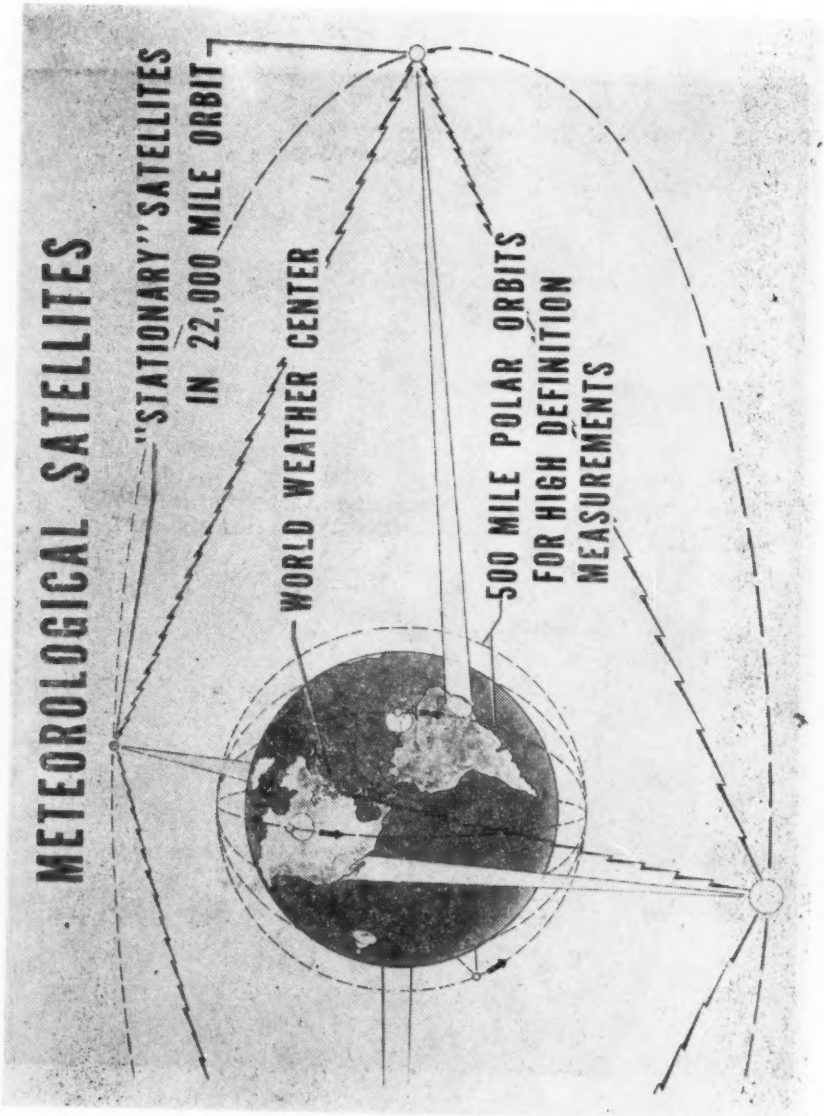
CHART SERIES 3

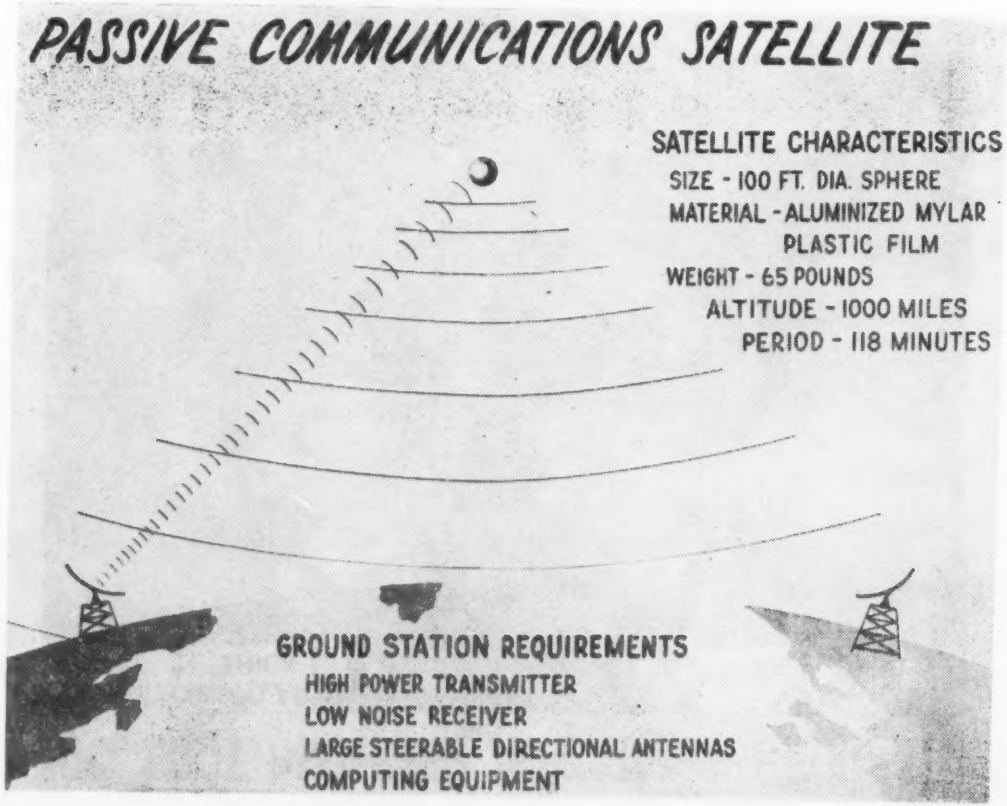
CHART SERIES 3



CLOUD COVER AND STORM DETECTION
NORTH
EAST

FIRST CLOUD COVER SATELLITE
SPIN
PICTURE RECONSTRUCTION

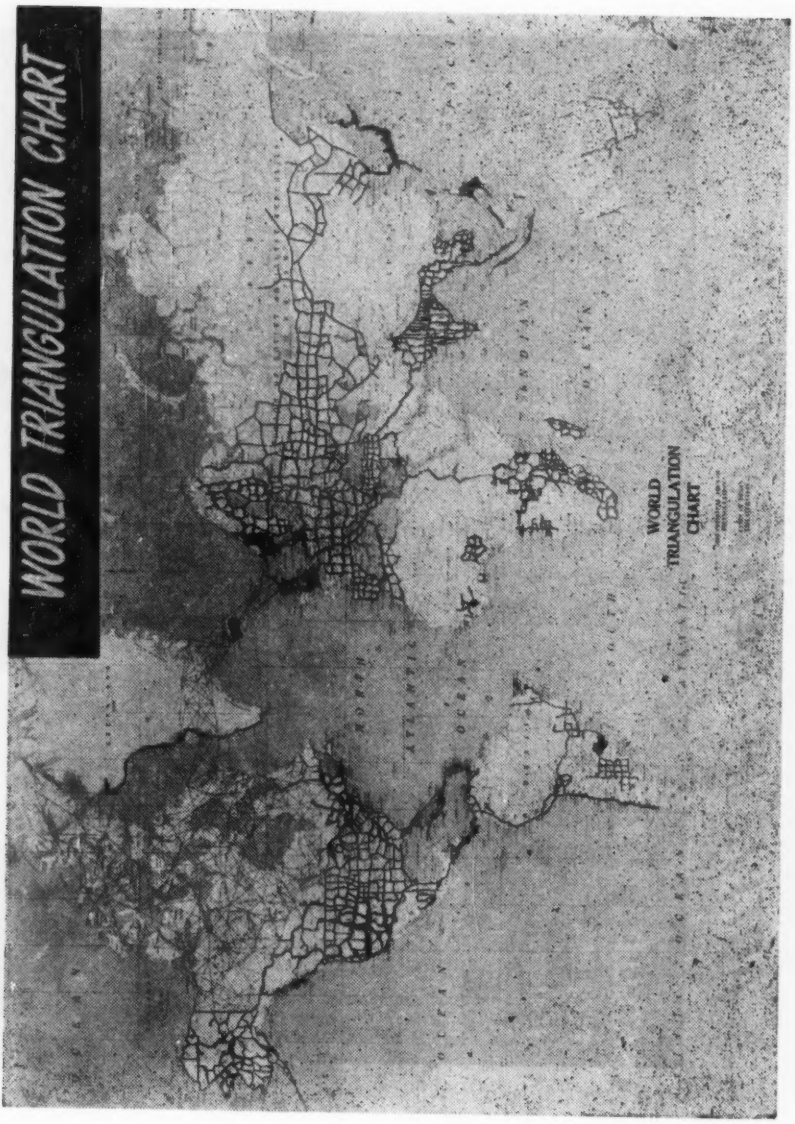

METEOROLOGICAL SATELLITES
"STATIONARY" SATELLITES
IN 22,000 MILE ORBIT
WORLD WEATHER CENTER
500 MILE POLAR ORBITS
FOR HIGH DEFINITION
MEASUREMENTS


PASSIVE COMMUNICATIONS SATELLITE
SATELLITE CHARACTERISTICS
SIZE - 100 FT. DIA. SPHERE
MATERIAL - ALUMINIZED MYLAR PLASTIC FILM
WEIGHT - 65 POUNDS
ALTITUDE - 1000 MILES
PERIOD - 118 MINUTES
GROUND STATION REQUIREMENTS
HIGH POWER TRANSMITTER
LOW NOISE RECEIVER
LARGE STEERABLE DIRECTIONAL ANTENNAS
COMPUTING EQUIPMENT

100 FOOT DIAMETER INFLATABLE SATELLITE
ALUMINIZED MYLAR
.00025 IN. THICK
WEIGHT
65 POUNDS

ACTIVE REPEATER SATELLITE
SATELLITE CONTAINS
RECEIVER
TRANSMITTER
ANTENNA
POWER SUPPLY
GROUND EQUIPMENT
RECEIVERS, STANDARD
TRANSMITTERS, NOMINAL POWER
ANTENNAS, STEERABLE
DIRECTIONAL

86015—59——11


WORLD TRIANGULATION CHART
WORLD TRIANGULATION CHART

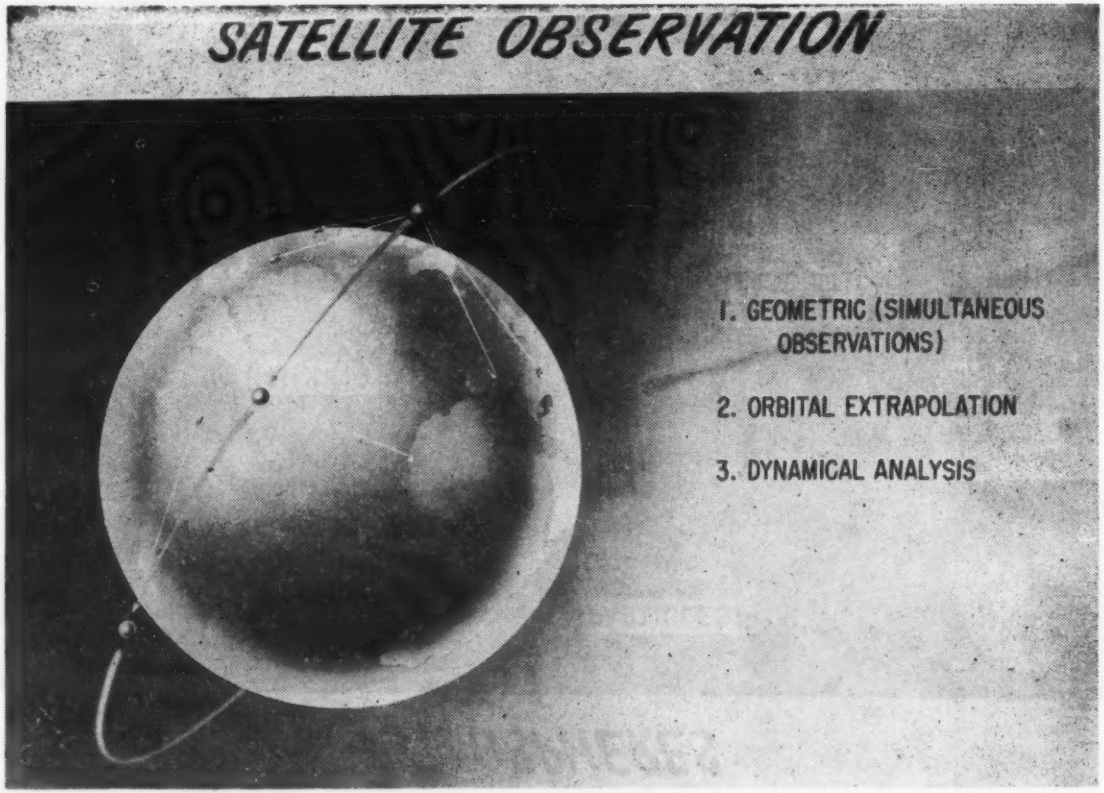
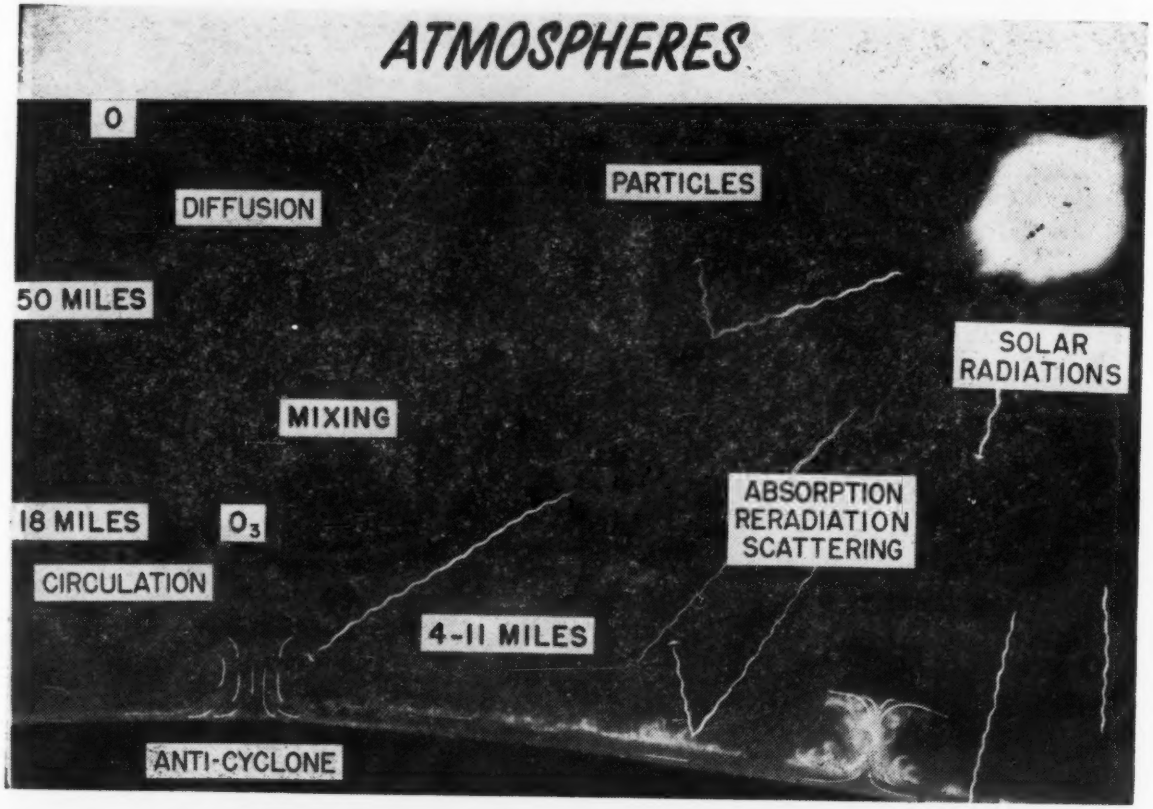

SATELLITE OBSERVATION
1. GEOMETRIC (SIMULTANEOUS OBSERVATIONS)
2. ORBITAL EXTRAPOLATION
3. DYNAMICAL ANALYSIS

CHART SERIES 4



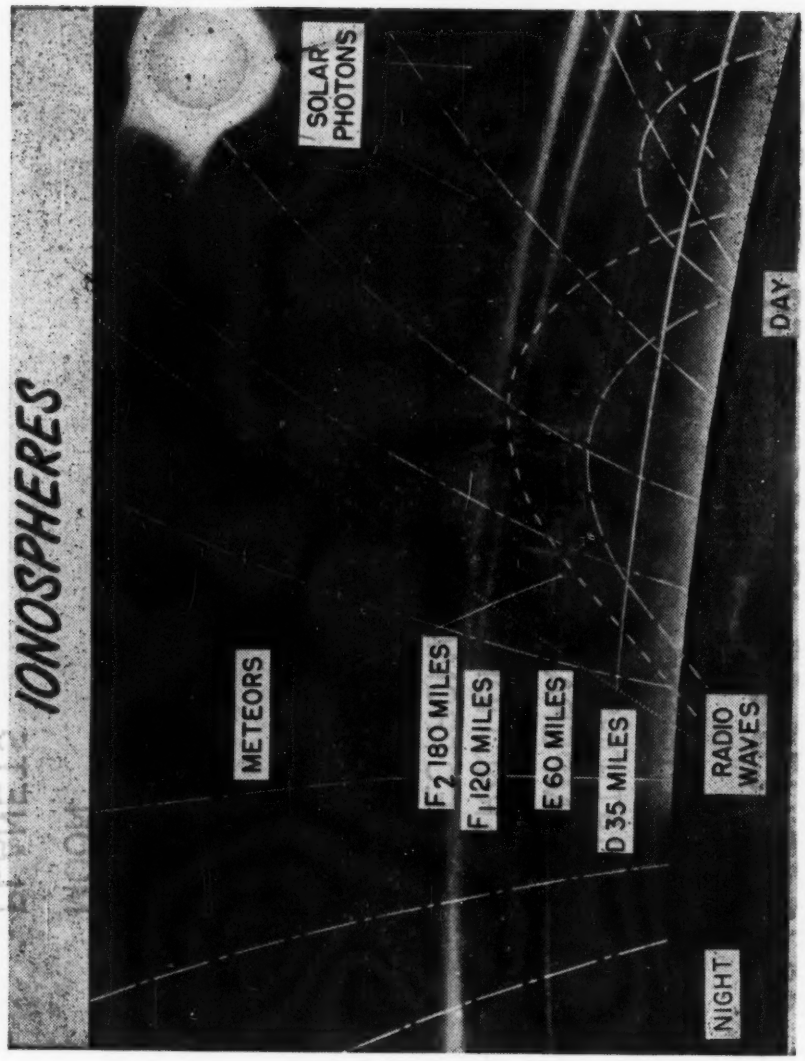
OBJECTIVES OF ATMOSPHERES STUDIES

EARTH'S UPPER ATMOSPHERE

- VARIATIONS OF DENSITY, PRESSURE, TEMPERATURE, COMPOSITION
- INTERACTIONS WITH PARTICLES AND ELECTROMAGNETIC RADIATIONS
- RELATIONS TO SURFACE METEOROLOGY
- RELATIONS TO SUN

OTHER ATMOSPHERES

- SUN
- MOON
- PLANETS


IONOSPHERES
METEORS
SOLAR PHOTONS
F2 180 MILES
F1 120 MILES
E 60 MILES
D 35 MILES
RADIO WAVES
NIGHT
DAY

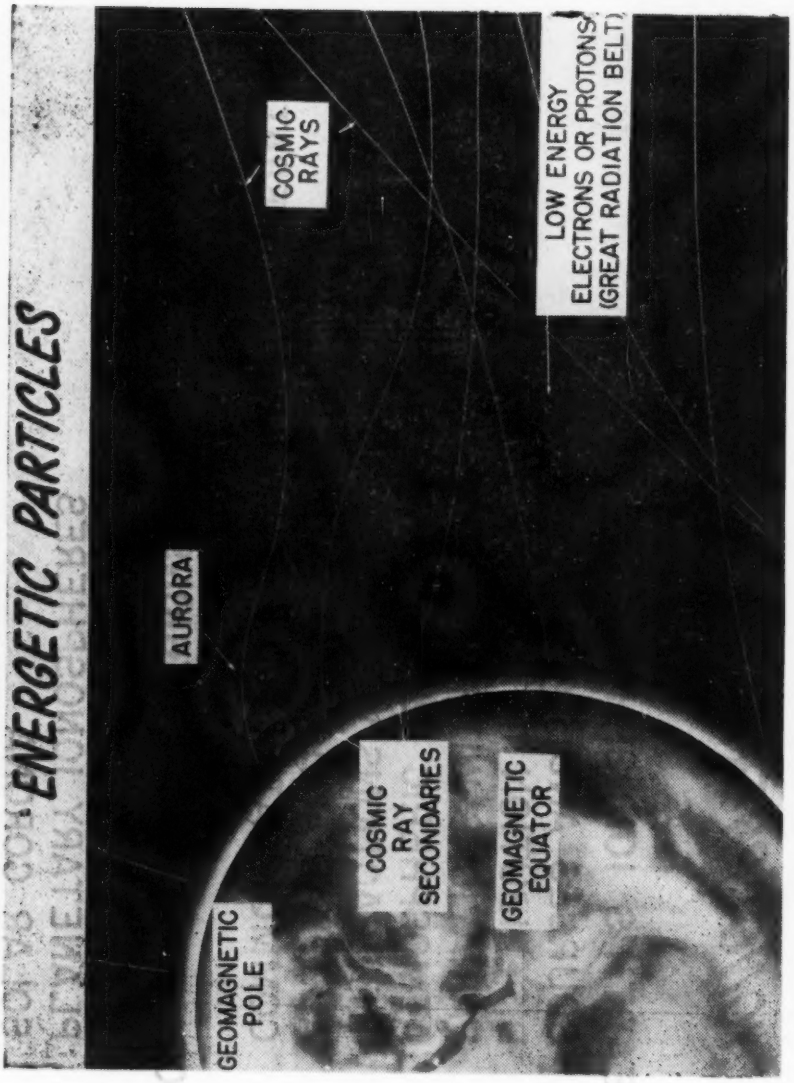
IONOSPHERES RESEARCH OBJECTIVES

EARTH'S IONOSPHERE

- SOURCES AND NATURE
- DISTRIBUTION IN SPACE
- VARIATIONS WITH TIME
- ATMOSPHERIC CURRENTS AND MAGNETIC FIELD
- INTERACTIONS WITH RADIATION AND PARTICLES
- AURORAS AND GREAT RADIATION BELT
- COMMUNICATIONS AND SPACE FLIGHT OPERATIONS

OTHER IONIZED REGIONS

- MOON'S IONOSPHERE
- PLANETARY IONOSPHERES
- SOLAR CORONA


ENERGETIC PARTICLES
AURORA
COSMIC RAYS
LOW ENERGY ELECTRONS OR PROTONS (GREAT RADIATION BELT)
GEOMAGNETIC POLE
COSMIC RAY SECONDARIES
GEOMAGNETIC EQUATOR

OBJECTIVES OF ENERGETIC PARTICLES STUDIES

COSMIC RAYS

AURORAL PARTICLES

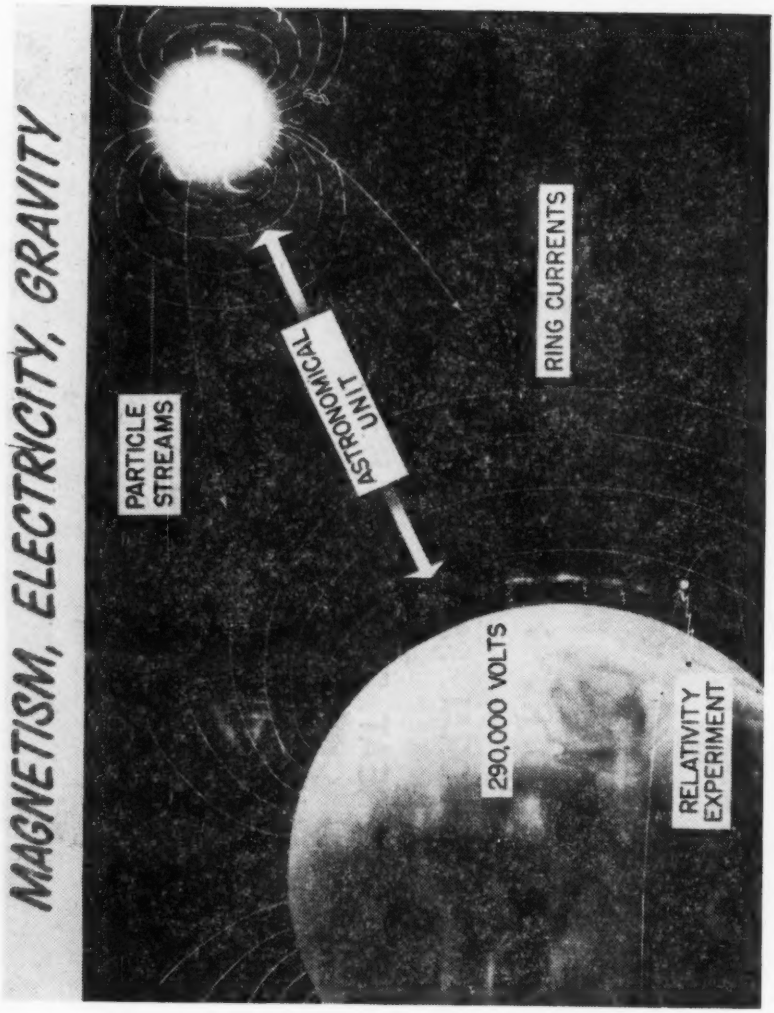
GREAT RADIATION BELT

INTERACTIONS OF PARTICLES WITH ATMOSPHERE

EFFECTS ON MATERIALS AND LIVING ORGANISMS

ORIGINS

36015—59——12


MAGNETISM, ELECTRICITY, GRAVITY
PARTICLE STREAMS
ASTRONOMICAL UNIT
RING CURRENTS
290,000 VOLTS
RELATIVITY EXPERIMENT

OBJECTIVES OF FIELD STUDIES

MAGNETIC FIELD INVESTIGATIONS:

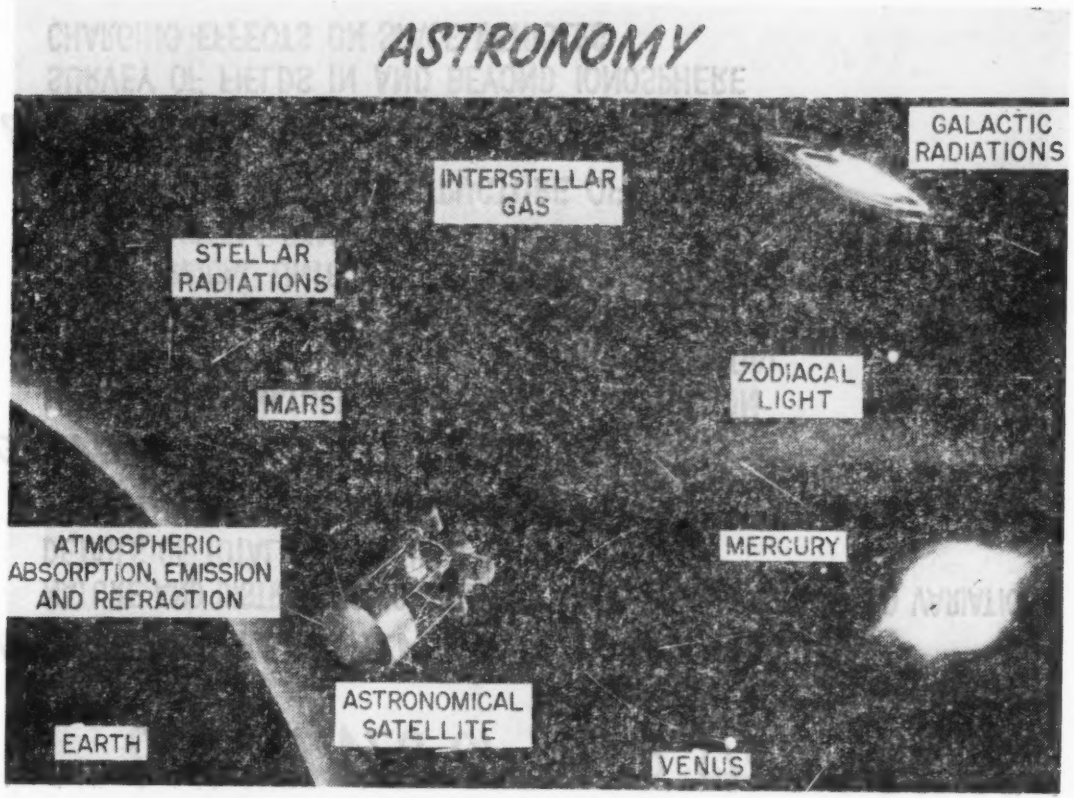
NATURE AND DISTRIBUTION OF ELECTRIC CURRENTS INDUCING FIELD VARIATIONS
DETAILS OF TOTAL EARTH FIELD
SOLAR, LUNAR, PLANETARY. AND INTERPLANETARY CHARACTERISTICS

GRAVITATIONAL FIELD INVESTIGATIONS:

FUNDAMENTAL NATURE AND ORIGIN OF GRAVITATION
TIME SCALE EFFECTS OF GRAVITATIONAL POTENTIAL
GRAVITATIONAL AND INERTIAL MASS COMPARISON
ASTRONOMICAL UNIT
SOLAR SYSTEM STABILITY
GEODESY AND INTERNAL STRUCTURE OF BODIES

ELECTRICAL FIELD INVESTIGATIONS:

SURVEY OF FIELDS IN AND BEYOND IONOSPHERE
CHARGING EFFECTS ON SPACE VEHICLES


ASTRONOMY
GALACTIC RADIATIONS
INTERSTELLAR GAS
STELLAR RADIATIONS
ZODIACAL LIGHT
MARS
ATMOSPHERIC ABSORPTION, EMISSION AND REFRACTION
MERCURY
ASTRONOMICAL SATELLITE
EARTH
VENUS

ASTRONOMY OBJECTIVES

SOLAR SYSTEM

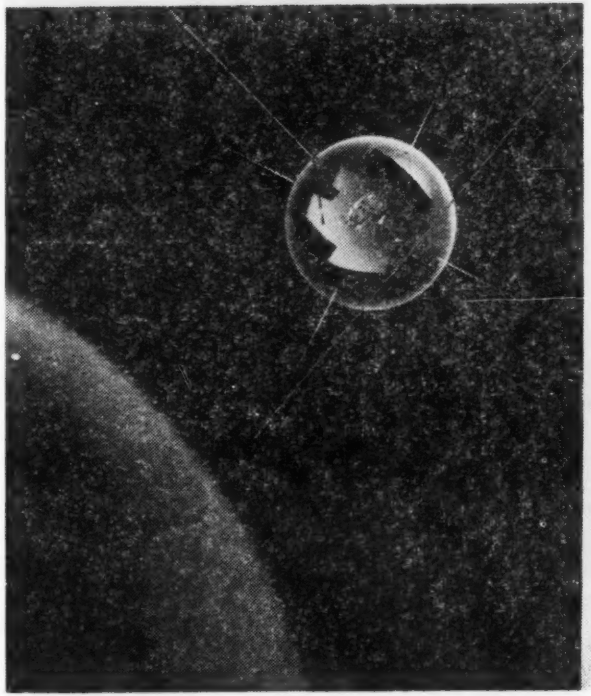
- SUN
- PLANETS
- MOON
- INTERPLANETARY MATTER

GALAXY

- STARS
- NEBULAS
- INTERSTELLAR MEDIUM

OTHER GALAXIES

BIOLOGY



FACTORS

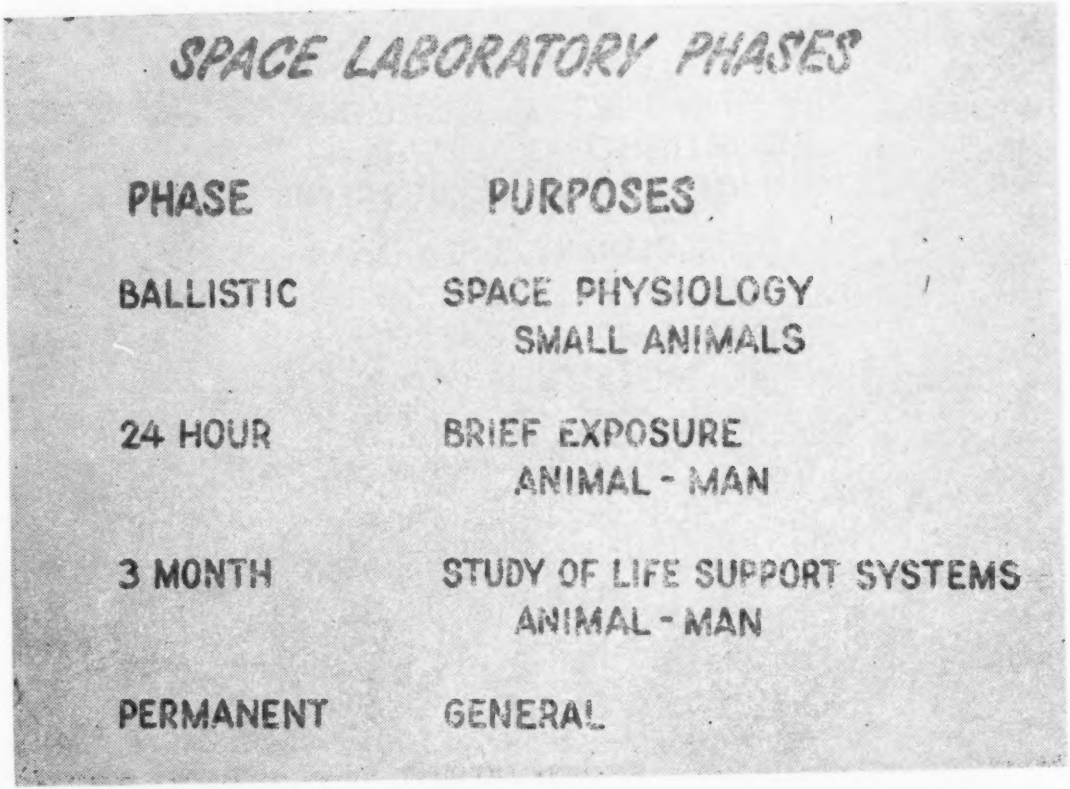
PSYCHOLOGICAL

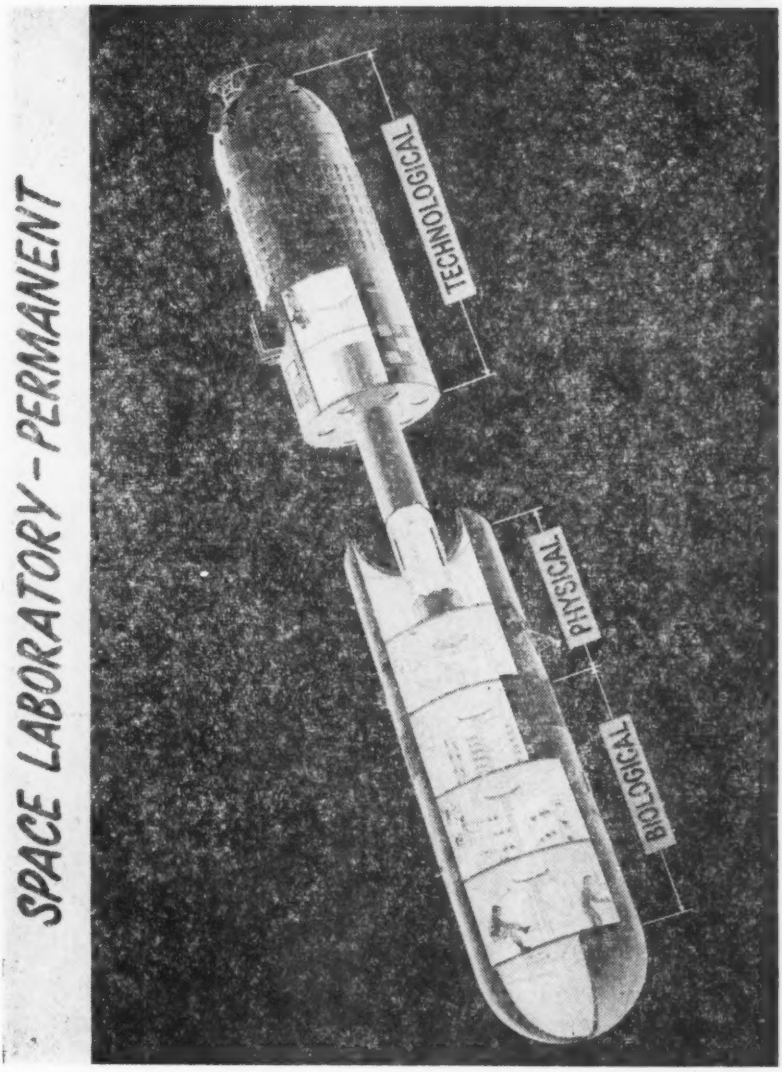
- WEIGHTLESSNESS
- ISOLATION
- CONFINEMENT
- RESTRAINT

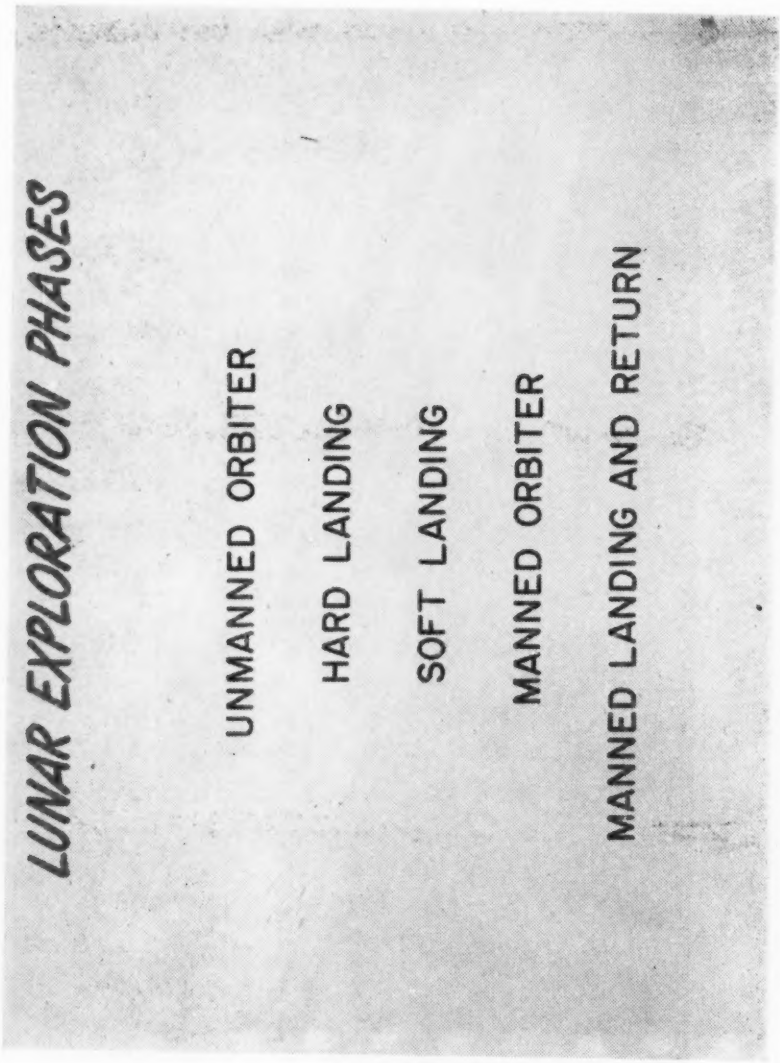
PHYSIOLOGICAL

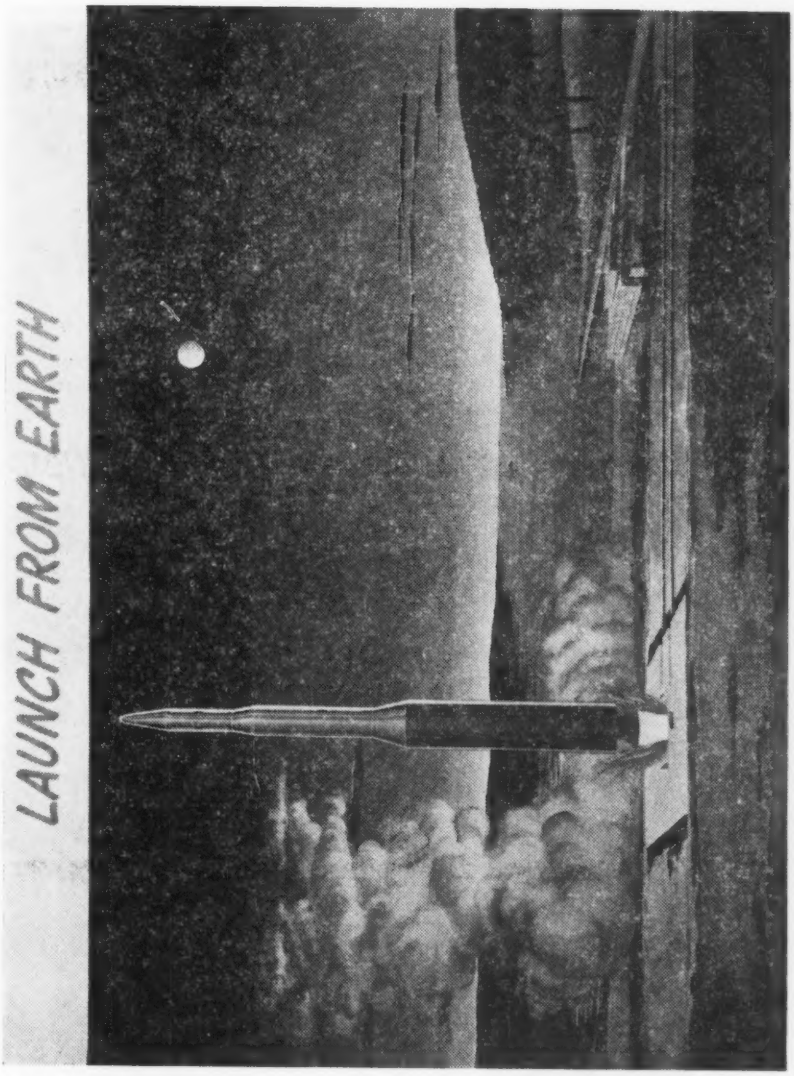
- RADIATIONS
- ENERGETIC PARTICLES
- ACCELERATION
- NOISE AND VIBRATION
- WEIGHTLESSNESS
- RHYTHMS

SPACE PROGRAMS
EARTH SATELLITES
SCIENTIFIC
APPLIED
ORBITING LABORATORIES
LUNAR EXPLORATION
PROBES AND ORBITERS
INSTRUMENT LANDINGS
MANNED LANDINGS
PLANETARY EXPLORATION
PROBES AND ORBITERS
INSTRUMENT LANDINGS
SOLAR PROBES

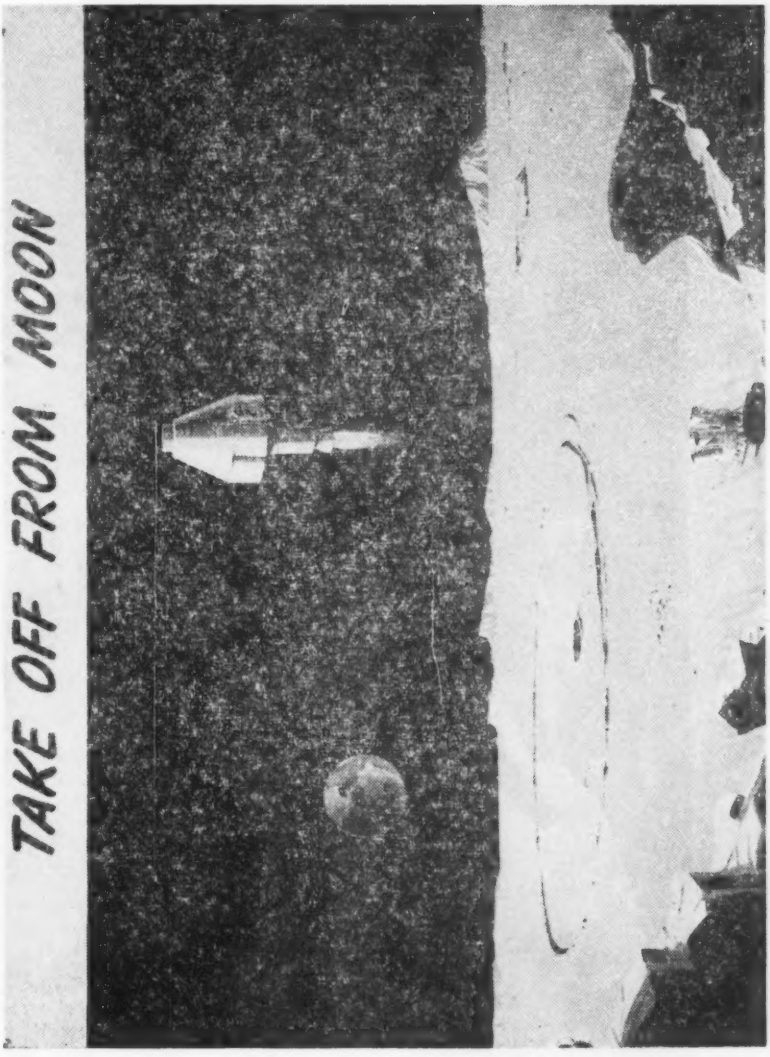

SPACE LABORATORY PHASES
PHASE
PURPOSES
BALLISTIC
SPACE PHYSIOLOGY
SMALL ANIMALS
24 HOUR
BRIEF EXPOSURE
ANIMAL - MAN
3 MONTH
STUDY OF LIFE SUPPORT SYSTEMS
ANIMAL - MAN
PERMANENT
GENERAL


SPACE LABORATORY - PERMANENT
TECHNOLOGICAL
PHYSICAL
BIOLOGICAL


LUNAR EXPLORATION PHASES
UNMANNED ORBITER
HARD LANDING
SOFT LANDING
MANNED ORBITER
MANNED LANDING AND RETURN


LAUNCH FROM EARTH

INITIATING LUNAR LANDING


TAKE OFF FROM MOON

RETURN TO EARTH

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